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THE ECONOMIC GEOLOGY OF THE UPPER FREEPORT COAL IN NORTHEASTERN GREENE COUNTY, PENNSYLVANIA

Viktoras W. Skema
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William E. Edmunds

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
OFFICE OF RESOURCES MANAGEMENT
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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PENNSYLVANIA GEOLOGICAL SURVEY

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PREFACE

The purpose of this report is to provide both a specific evaluation of the economic potential of the Upper Freeport coal in the immediate area of northeastern Greene County, and a better general understanding of this coal throughout western Pennsylvania. This is the second report by the Pennsylvania Geological Survey on the detailed stratigraphy, sedimentology, and economic geology of the Upper Freeport coal in specific portions of western Pennsylvania; the first report was on the Upper Freeport coal in the New Stanton area of Westmoreland County (Mineral Resource Report 75).

Increasing demands for energy sources have created considerable interest in the Upper Freeport coal in southwestern Pennsylvania. In much of the area, the coal is deeply buried. Because of this, and the fact that the more persistently thick and continuous Pittsburgh coal is found closer to the surface, the Upper Freeport coal has not been sought in the past. Available evidence shows that the Upper Freeport coal is present in minable quantities. However, its depth and discontinuous occurrence necessitate thorough and careful exploration and evaluation. This requires a proper understanding of the geology of the Upper Freeport coal and the rocks surrounding it. Specifically, it involves careful examination of the internal characteristics, lateral distribution, and vertical sequences of these rocks. In this way a model of the depositional environment of the coal and associated sediments can be developed that will improve the predictability of the characteristics and distribution of these deposits beyond the specific area where geologic data are available. This report develops such a model in northeastern Greene County. It provides coal geologists and engineers who are involved in exploration and mine planning detailed information about the Upper Freeport coal and its roof rocks in northeastern Greene County, and should help develop a better understanding of the general characteristics of the coal in southwestern Pennsylvania.

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by

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ABSTRACT

The Upper Freeport coal and associated rocks in the Mather and Waynesburg quadrangles of northeastern Greene County, Pennsylvania, were studied to more accurately determine the coal resources of the area and to establish criteria to aid future coal exploration.

Nearly all data are derived from drill core logs. Geophysical logs from gas wells provided some data, particularly about the characteristics of sandstones. Correlation between holes is based mainly on marine zones and coals. Generally, several beds should be used for correlation because marine zones and especially coals are absent locally and can vary in stratigraphic position. The Lower Bakerstown coal was used as the stratigraphic datum horizon in this study, and was only locally absent.

The Upper Freeport coal in this area was originally formed in an interdistributary swamp, but its deposition was disrupted when rivers changed course to achieve lower gradients and inundated the swamp. The Upper Freeport coal is lense shaped and grades laterally into river-deposited sandstones and levees to the west, freshwater lake deposits to the east, and overbank muds and possible lake deposits to the south. This lense is approximately 10 miles (16 km) wide in an east-west direction and 13 miles (21 km) long in a north-south direction. The coal has a well-defined linear western and northwestern limit which can be traced from just west of the town of Waynesburg northward and westward to the northeastern corner of the Waynesburg quadrangle and into the southern part of the Ellsworth quadrangle. The eastern boundary of the Upper Freeport coal is not as well defined; the coal is generally thinner and in some places is absent in the eastern and southern part of the Mather quadrangle. The coal at the margins is generally highest in sulfur and ash, and contains the most partings. The Upper Freeport is overlain by sandstones and shales deposited in upper delta plain to river environments. The coal is partly cut out by later deposits in only one known location. Locally hazardous roof conditions at the margins of overlying channel-fill sandstones may require special planning for underground mining.

The Upper Freeport coal of the lenticular area studied occupies 86 square miles (223 km^2) at depths of 985 to 1,500 feet (300 to 460 m) and contains measured reserves of 79,211,400 tons (71,859,373 MT) of coal greater than 42 inches (107 cm) thick. The coal has a sulfur content of 0.81 to 2 percent and an ash content of 7 to 24 percent.

It has long been held that significant amounts of Upper Freeport coal are present in southwestern Pennsylvania. This report shows that the Upper Freeport coal in this particular area is present as discontinuous lenses separated by areas of no coal. As a result of this study it is concluded that the distribution and characteristics of the Upper Freeport coal can be best predicted by assembling stratigraphic details on an area-by-area basis and by comparing them with modern deposits of peat forming in environments similar to those in which the coal formed.

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INTRODUCTION

The area of this study on the Upper Freeport coal covers most of the Waynesburg and Mather quadrangles, and parts of southern Ellsworth, southwestern California, and northern Garards Fort and Oak Forest quadrangles in northeastern Greene County, southern Washington County, and western Fayette County, Pennsylvania. The location and extent of this study were determined in large measure by the availability of data. The study is based on logs of cored drill holes, and, to a minor degree, on gamma-ray and sample logs from gas wells (Figure 1).

Individual holes are identified on the location map and in the text by an eight-digit number. The first four numbers give the minutes and seconds of latitude. The last four numbers represent the minutes and seconds of longitude.

An attempt was made to extract from the available data all possible information related to the economically important characteristics and distribution of the coal and associated rocks. Coal, like other sedimentary rocks, was deposited in specific environments in association with other sediments, and those environments of deposition strongly influenced the characteristics of the coal (Frazier and Osanek, 1969; Gould, 1970; Gould and Morgan, 1962). Recognition of these various depositional environments can be useful in coal exploration in any given area. The correlation of beds and interpolation of physical characteristics between various locations as used in coal studies of the past is an inadequate and oversimplified procedure. A more complete approach involves derivation of the most probable depositional environment by comparing the observed characteristics of the coal and associated rocks with similar modern sediments (Donaldson, 1969, 1974; Ferm, 1974; Ferm and Cavaroc, 1969; Horne and others, 1978). In this way, an understanding of the geography and geomorphology existing at the time of deposition is developed. Such an understanding allows a more accurate prediction of the distribution and characteristics of the coal and surrounding rocks between and beyond the locations from which data are collected.

The first step in developing an understanding of the Upper Freeport coal in northeastern Greene County involved close examination of the stratigraphy of the uppermost part of the Allegheny Group, and the entire overlying Glenshaw Formation of the Conemaugh Group. Correlation of key beds within the Glenshaw allowed a reliable correlation of the Upper Freeport coal to be made. After accurate correlations were established, it was possible to determine the three-dimensional geometry of these rocks. Analysis of this stratigraphic framework permitted the drawing of paleoenvironmental maps based on comparison with modern depositional conditions and reconstructions of the paleogeography of the coal and overlying strata.

In addition to the detailed examination of stratigraphy and sedimentology, the structural aspects of the Upper Freeport coal and associated rocks were considered. Structure contours on the coal were mapped, and available information on jointing in the overlying rocks was assembled and analyzed.

ACKNOWLEDGEMENTS

We wish to thank the officials of the Jones and Laughlin Steel Corporation for their generous cooperation in this project. Special thanks are offered to Mr. Herbert E. Steinman, chief mining engineer of the company's Vesta-Shannopin Coal Division, and to Mr. William Andrews, geologist with Jones and Laughlin. This project would not have been possible without the records and information supplied by these people.

We also greatly appreciate the able assistance of Michael K. McInerney in the preparation of this report for publication.

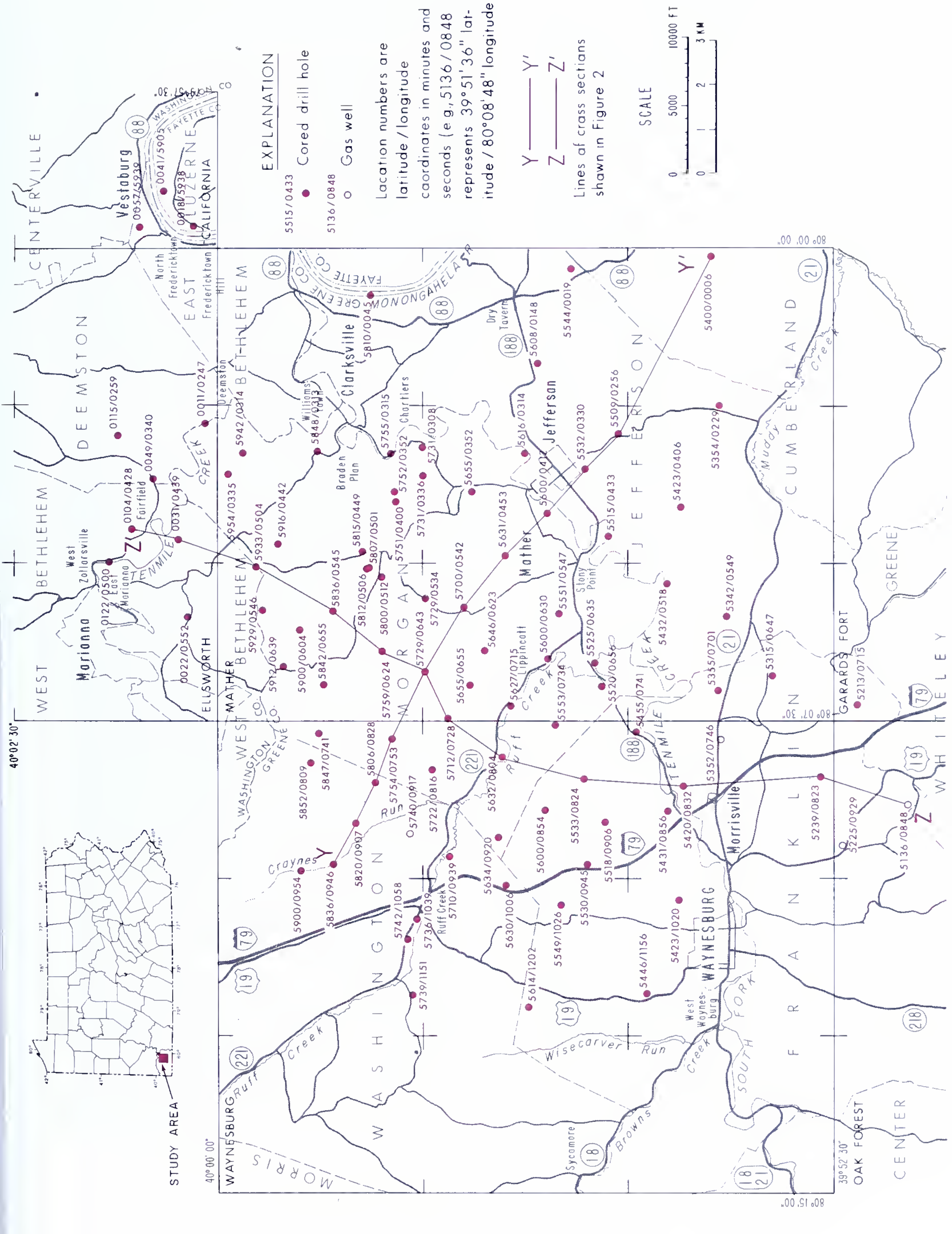


Figure 1. Map of the study area, showing locations of drill holes and gas wells.

STRATIGRAPHY

The stratigraphic interval covered in this report is limited to the Upper Freeport coal horizon of the Allegheny Group and the overlying Glenshaw Formation of the Conemaugh Group. This interval is approximately 1,000 feet (300 m) below the surface, where rocks of the Dunkard Group are exposed. The Pittsburgh coal at the base of the Monongahela Group is the most prominent bed above the rock sequence considered in this report, and serves as the most important stratigraphic marker horizon in the study area and throughout much of southwestern Pennsylvania. The interval between the top of the Upper Freeport coal and the base of the Pittsburgh coal (the lower and upper limits of the Conemaugh Group) ranges from 554 to 612 feet (169 to 187 m) in northeastern Greene County.

The Conemaugh rock sequence was assigned group status and divided into the Glenshaw and Casselman Formations by Flint in southern Somerset County (Flint, 1965). The Ames limestone, recognized as a very persistent horizon in the Conemaugh, was utilized in dividing the two formations. The predominantly nonmarine shale, siltstone, and fine sandstone interbedded with some freshwater limestone, lying between the top of the Ames and the base of the Pittsburgh coal, were named the Casselman Formation. The Glenshaw Formation was defined as the interval from the top of the Upper Freeport coal to the top of the Ames and contains several persistent, thin, fossiliferous marine zones. Though thin, these deposits were formed in an open sea of broad extent which was well enough established to support diverse marine invertebrate fauna. These marine beds are associated with a variety of thicker, markedly discontinuous sandstones, siltstones, and shales and are useful as key beds, especially on a local basis.

The Upper Freeport coal is a major coal in southwestern Pennsylvania, exceeded in prominence only by the Pittsburgh coal. In areas at or near the surface where the Upper Freeport has been mapped, thicknesses as great as 6 to 7 feet (1.8 to 2.1 m) have been reported (Johnson, 1928). Its thickness, however, is much more variable than that of the Pittsburgh coal, and reported "cutouts" of the coal are numerous. Recent work by the authors in the New Stanton area of Westmoreland County (Sholes and others, 1979) shows the Upper Freeport coal there to be of very limited areal extent. The coal in that area is bounded on two sides by sandstones which appear to be contemporaneous fluvial channel deposits. The coal and sandstone are interpreted as having formed in an upper delta plain or alluvial plain, an environment believed to be typical for the Upper Freeport in most of southwestern Pennsylvania.

This type of environment in modern coastal areas is characterized by low relief, frequent changes in courses of streams, and pronounced lateral discontinuity of beds. Peat develops in broad backswamp areas, which are bordered by narrow distributary stream channels and levees in which sand and silt are being deposited. Occasionally the streams change course by invading a peat swamp where a more favorable downward gradient exists. Widespread deposition of sand and silt over the peat swamp occurs in the early stages of this process; as a new channel and levee system develops, deposition is gradually limited to a narrow belt. Peat development is terminated in areas of the swamp where a new channel is forming. Eventually a new peat deposit can form over the abandoned channel-levee system and over some of the clastics first dumped into the swamp.

Discounting such factors as original topographic differences of elevation and differential compaction after burial, the amount of sediment deposited between the cessation of the original peat accumulation and the beginning of the next peat development will determine the vertical spacing of the two peats. In areas far enough from the new stream course where peat development is only briefly interrupted, this difference can be nearly imperceptible. In areas closer to the newly developed stream course, sufficient sediment is initially deposited over the older peat to create a distinct vertical separation between it and the younger one.

This is a simplification of one of many deltaic sedimentary processes, presented to illustrate the complexity of the probable depositional environment of the Upper Freeport coal in southwestern Pennsylvania. It would be very easy to make an erroneous correlation of the discontinuous lenses of coal, possibly occupying different vertical positions, which form in this type of environment. This possibility makes careful correlation of the overlying, more laterally continuous marine zones in the Glenshaw Formation an important first step in any attempt at correlating the Upper Freeport coal.

In northeastern Greene County, four major marine zones can be found in the Glenshaw (Figure 2). On the basis of lithologic characteristics and relative positions within the formation, these zones correlate well with the four major marine zones described by Flint in southern Somerset County: (in descending order) the Ames, Woods Run (Friendsville, Portersville), Pine Creek (Cambridge), and Brush Creek.

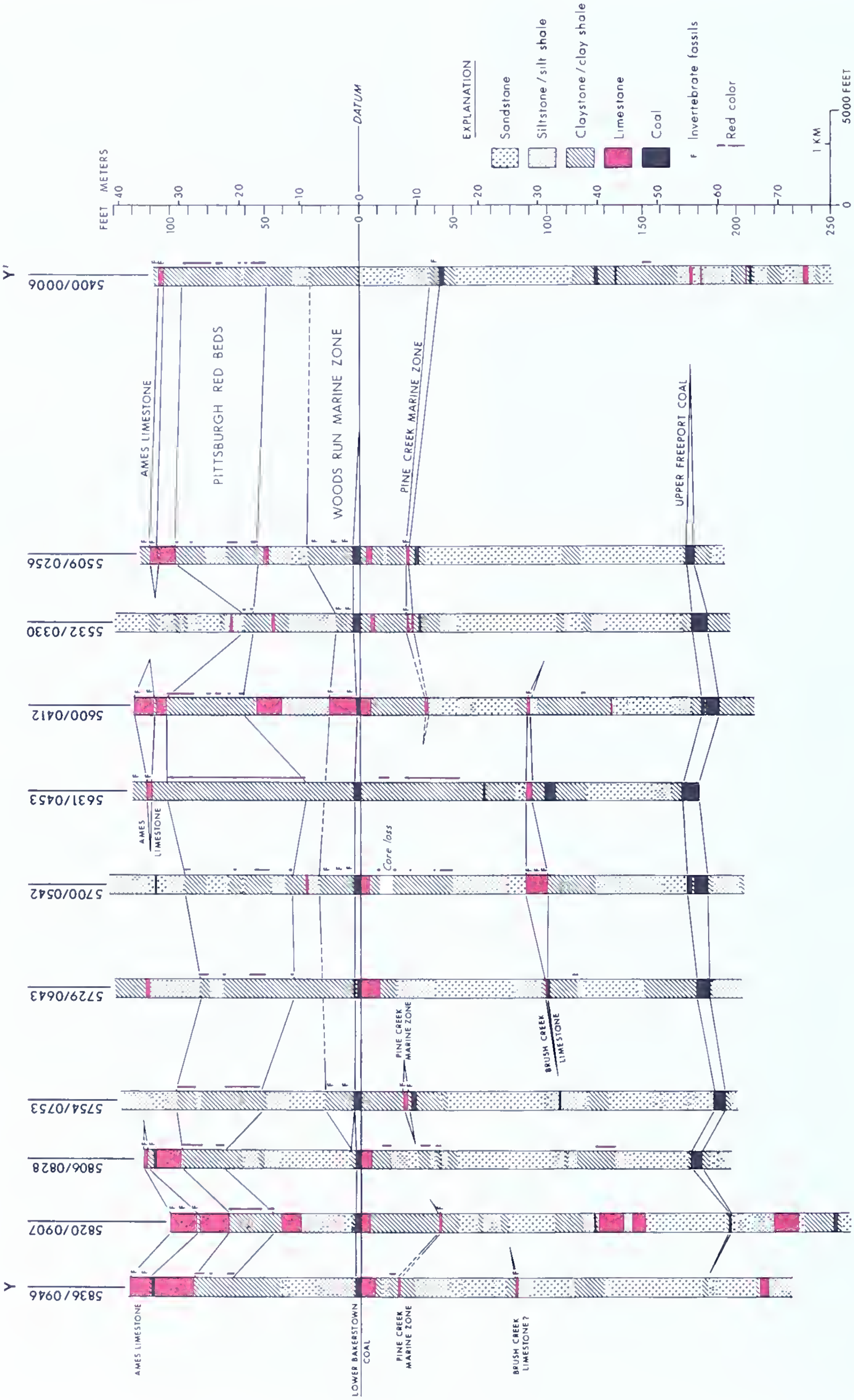
The most persistent of marine zones in this report area is the Ames. It is most often described in drill hole logs obtained from the Jones and Laughlin Steel Corporation as a limestone containing abundant invertebrate fossils. In several holes the limestone has fossiliferous gray and green shales both above and below it. The fossils in the Ames were termed marine; however, detailed descriptions were not given in the logs. The limestone is usually 4 to 7 feet (1.2 to 2.1 m) thick and attains a maximum thickness of about 15 feet (4.6 m). Even though generally persistent, the Ames is absent locally in the study area. The few areas where it is missing are usually occupied by sandstone and siltstone.

The Woods Run is the next most persistent marine zone in the study area. The interval between it and the Ames is approximately 90 to 100 feet (27 to 30 m). It is a black shale and often contains only a few marine fossils. Rarely, it is reported as a black to dark-gray fossiliferous limestone. In the northern part of the Mather quadrangle, a 1-foot- (0.3-m-) thick marine limestone overlies 12 to 13 feet (3.7 to 4.0 m) of black fossiliferous shale. The Woods Run is normally 10 to 15 feet (3.0 to 4.6 m) thick. As in the Ames horizon, the few areas where the marine zone is missing contain sandstone.

A third marine zone, the Pine Creek (Cambridge), is 25 to 45 feet (7.6 to 13.7 m) below the base of the Woods Run. It is usually a thin limestone that contains abundant marine fossils, but has also been reported as limy shale or black shale containing marine fossils. It is neither as continuous as the Ames or Woods Run, nor is its stratigraphic position as well defined. In one drill hole two marine zones separated by 13 feet (4.0 m) of clay shale containing a thin coal were reported at the Pine Creek horizon.

The Brush Creek is also sometimes discontinuous. However, this marine zone maintains a uniform interval of about 85 to 105 feet (26 to 32 m) to the base of the Woods Run marine zone. Where present, it is nearly always a thin marine limestone, often overlain by several feet of fossiliferous black shale. Rarely is the black shale alone present. The Brush Creek is often laterally adjacent to sandstone. In one area, it appears to be cut out by an overlying sandstone body (Figure 3H).

In addition to these four major marine zones, one possible occurrence of a distinctly separate marine zone was found in a drill hole at the western edge of the study area. This was a 5-foot- (1.5-m-) thick bed of black shale containing a few invertebrate fossils, located 50 feet (15 m) below the Ames limestone. The fossils were not identified in the Jones and Laughlin drill hole log, but were described as being


Y'
Y
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5600/0412
5631/0453
5700/0542
5729/0643
5754/0753
5806/0828
5820/0907
5836/0946
AMES LIMESTONE
PITTSBURGH RED BEDS
WOODS RUN MARINE ZONE
PINE CREEK MARINE ZONE
UPPER FREEPORT COAL
AMES LIMESTONE
Core loss
PINE CREEK MARINE ZONE
BRUSH CREEK LIMESTONE
LOWER BAKERSTOWN COAL
BRUSH CREEK LIMESTONE?
DATUM
FEET
METERS
EXPLANATION
Sandstone
Siltstone / silt shale
Claystone / clay shale
Limestone
Coal
F Invertebrate fossils
Red color
1 KM
5000 FEET
0
40
30
20
10
0
10
20
30
40
50
60
70
100
50
0
50
100
150
200
250

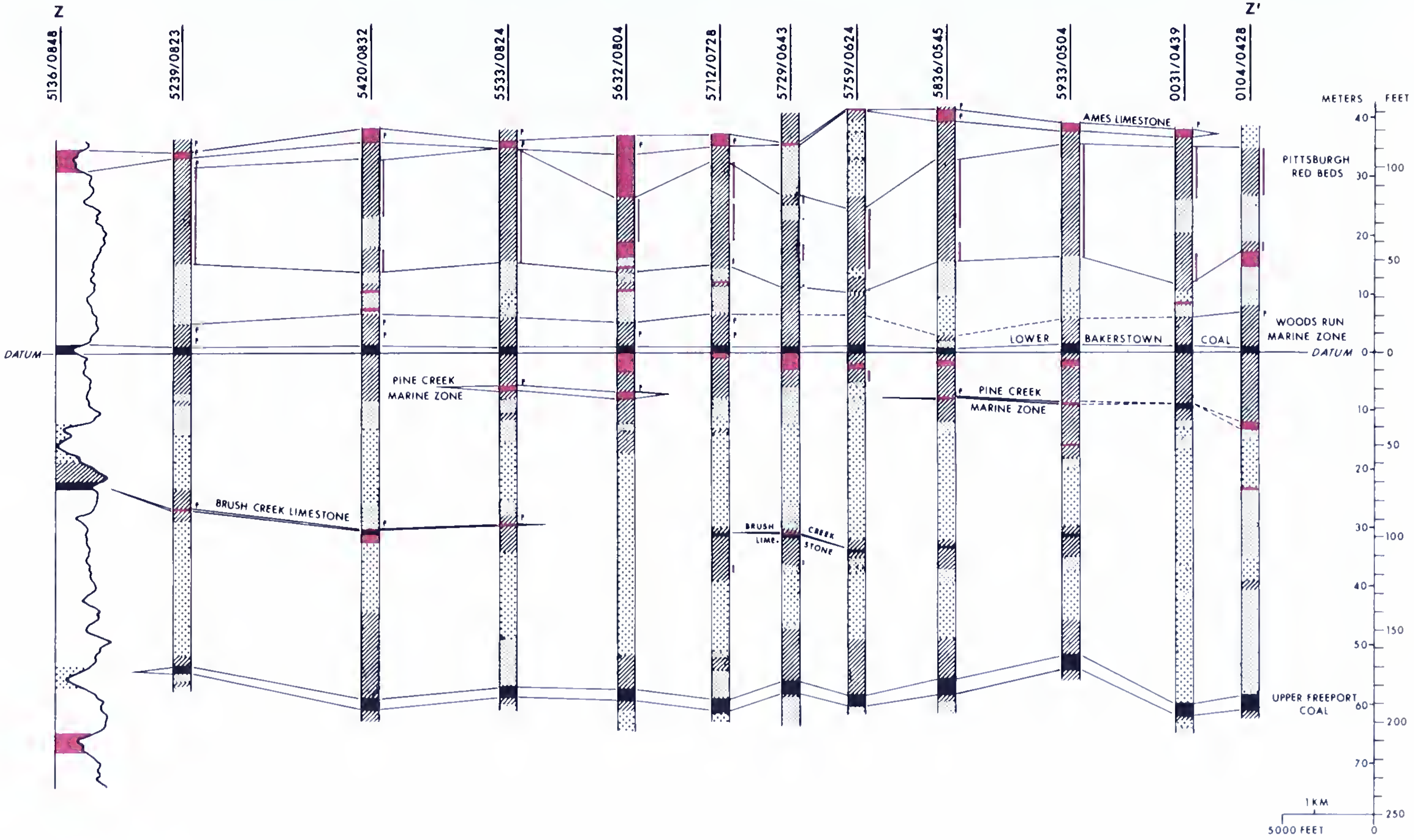


Figure 2. Stratigraphic cross sections of the Upper Freeport to Ames interval.

marine. This fossiliferous black shale is directly above a thin coal which lies 4 feet (1.2 m) above an 8-foot- (2.4-m-) thick, shaly gray limestone. At this stratigraphic position, the sequence of beds would normally be called the Ewing limestone and the Upper Bakerstown coal. A limestone overlying the Upper Bakerstown coal and containing marine invertebrate fossils has recently been reported in eastern Ohio and is named the Noble limestone (Murphy and Picking, 1967). The fossiliferous black shale reported in northeastern Greene County is probably laterally equivalent to the Noble limestone.

The Ames and Woods Run are clearly the most widespread recognizable marine zones in the Glenshaw Formation of northeastern Greene County. They are very reliable stratigraphic guides in the area. In addition to these marine zones, the Pittsburgh red beds and the Lower Bakerstown coal have great continuity throughout the study area. The Pittsburgh red beds are recognized in this report as the stratigraphic interval directly below the Ames limestone in which the predominant rock type is red claystone. The average thickness of these red beds is approximately 45 feet (14 m); they range in thickness from 5 to 75 feet (1.5 to 23 m).

The Lower Bakerstown coal is present in all but two of the holes drilled in the study area. It has a persistent thickness of about 3 feet (1 m), and is always located directly beneath the Woods Run marine zone. The Lower Bakerstown was chosen as the key horizon for stratigraphic correlation in the Glenshaw of northeastern Greene County because it is the most continuous, uniformly thin bed directly associated with a major marine zone. The base of the coal is used as the datum for most of the cross sections in this report.

SEDIMENTOLOGY

GENERAL

The distinguishing sedimentological feature of the rocks in the upper Allegheny Group and lower Glenshaw Formation up to the Brush Creek limestone is the discontinuous nature of the lithologic units. With the establishment of a general stratigraphic framework based on the use of the marine zones in the Glenshaw Formation as key beds, an examination of the sedimentology at and near the Upper Freeport horizon was possible. In order to better understand the vertical and lateral relationship of the rocks in this part of the section, cross sections of the interval from just below the Upper Freeport coal up to just above the Brush Creek limestone horizon were constructed, and maps showing the lateral distribution of these sediments were drawn (Figures 3, 4, 5, 6, and 7). Over much of the area, the part of the section above the Upper Freeport coal is characterized by lenticular, elongate sandstone bodies which grade laterally into sand-silt laminites and siltstones. In several areas, this sequence of sandstones and siltstones grades laterally into claystone and clay shale which occupy the entire interval between the Upper Freeport and Brush Creek horizons. Where this situation exists, a zone of red claystone is found approximately 20 to 40 feet (6 to 12 m) below the Brush Creek limestone.

Smaller, isolated lenses of fine-grained sandstone occur at and beneath the Upper Freeport horizon and rarely in the part of the section immediately below the Brush Creek. These are often associated with argillaceous limestones and calcareous claystones.

Coals are found throughout much of this part of the section. There are several thin coals, approximately 1 foot (0.3 m) or less thick, in the interval 40 feet (12 m) below the Brush Creek limestone, and several more thin coals exist within 60 feet (18 m) below the Upper Freeport seam. All of these coals, including the thick Upper Freeport, are laterally discontinuous and are often split.

UPPER FREEPORT COAL

The Upper Freeport coal in northeastern Greene County is greater than 60 inches (152

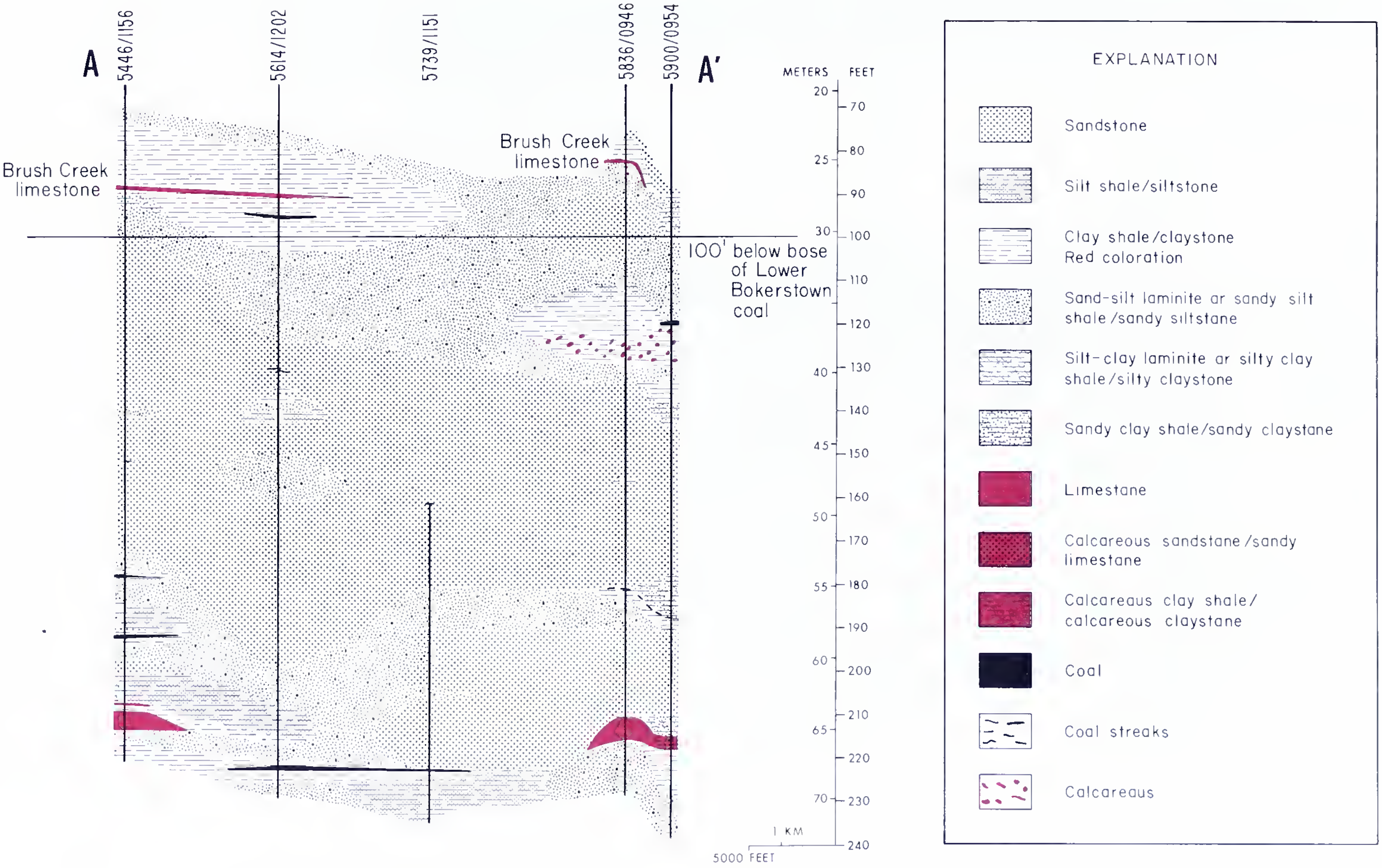
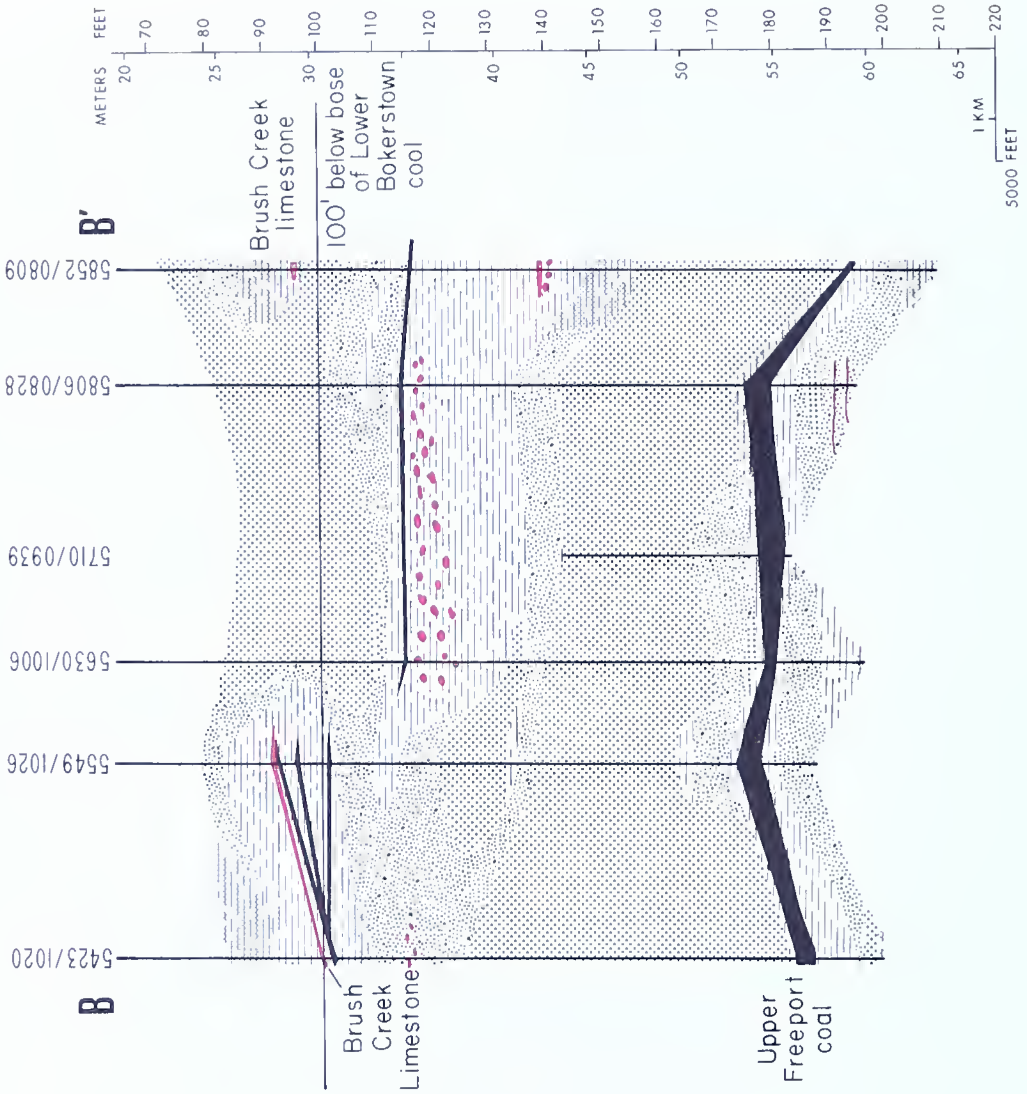


Figure 3. Stratigraphic cross sections of the Upper Freeport to Brush Creek interval.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5710/0939
5806/0828
5852/0809
Brush Creek limestone
100' below base of Lower Bakerstown coal
Brush Creek Limestone
Upper Freeport coal
METERS
FEET
20
25
30
40
45
50
55
60
65
70
80
90
100
110
120
130
140
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180
190
200
210
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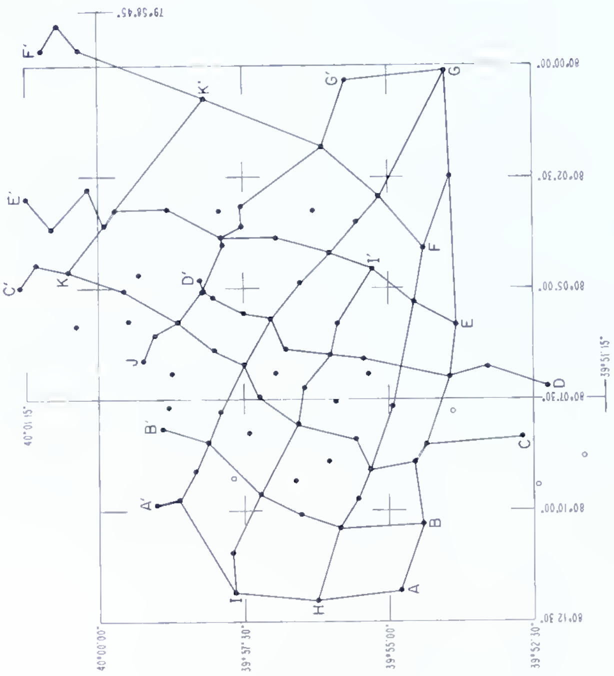
1 KM
5000 FEET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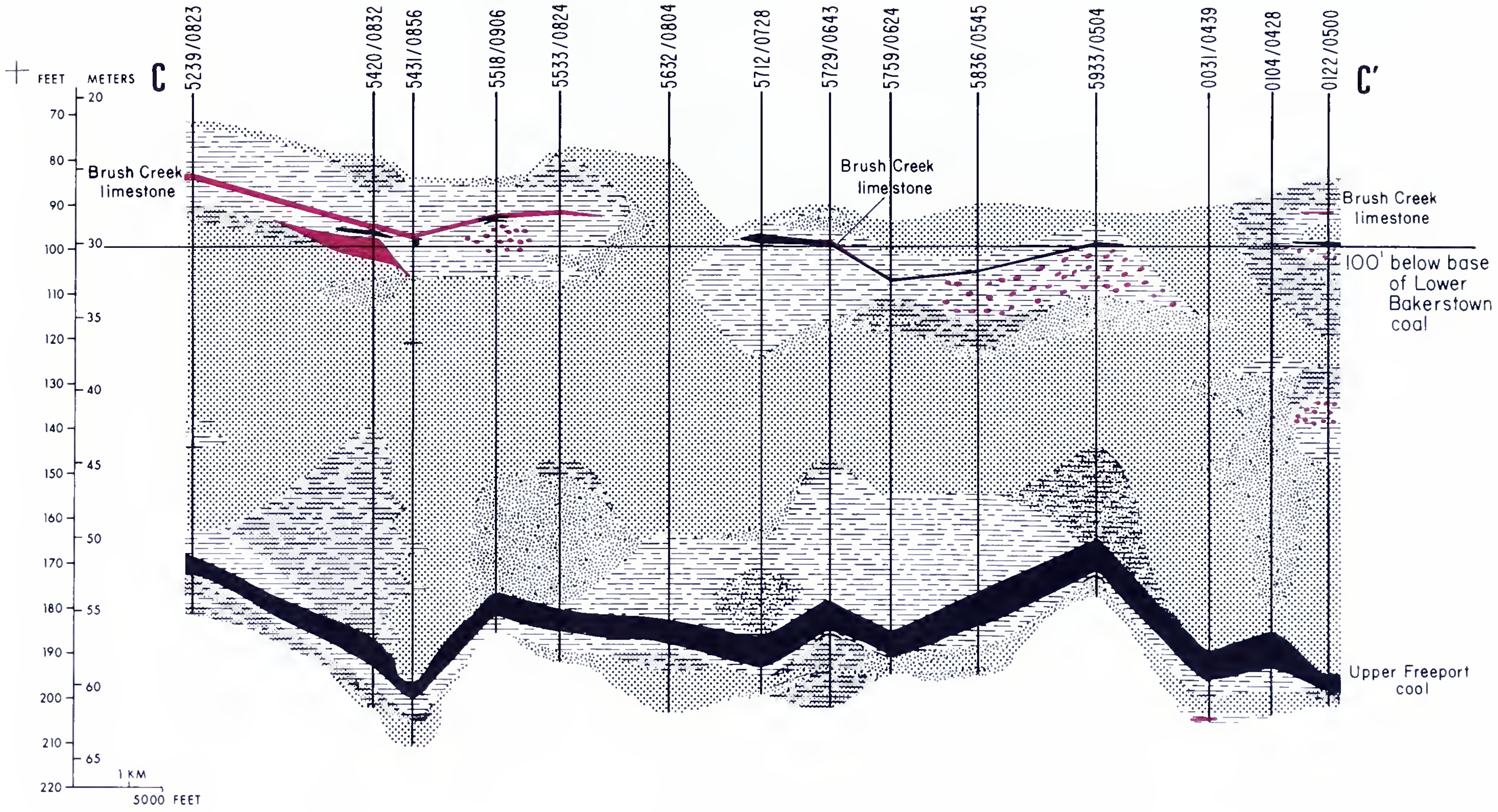

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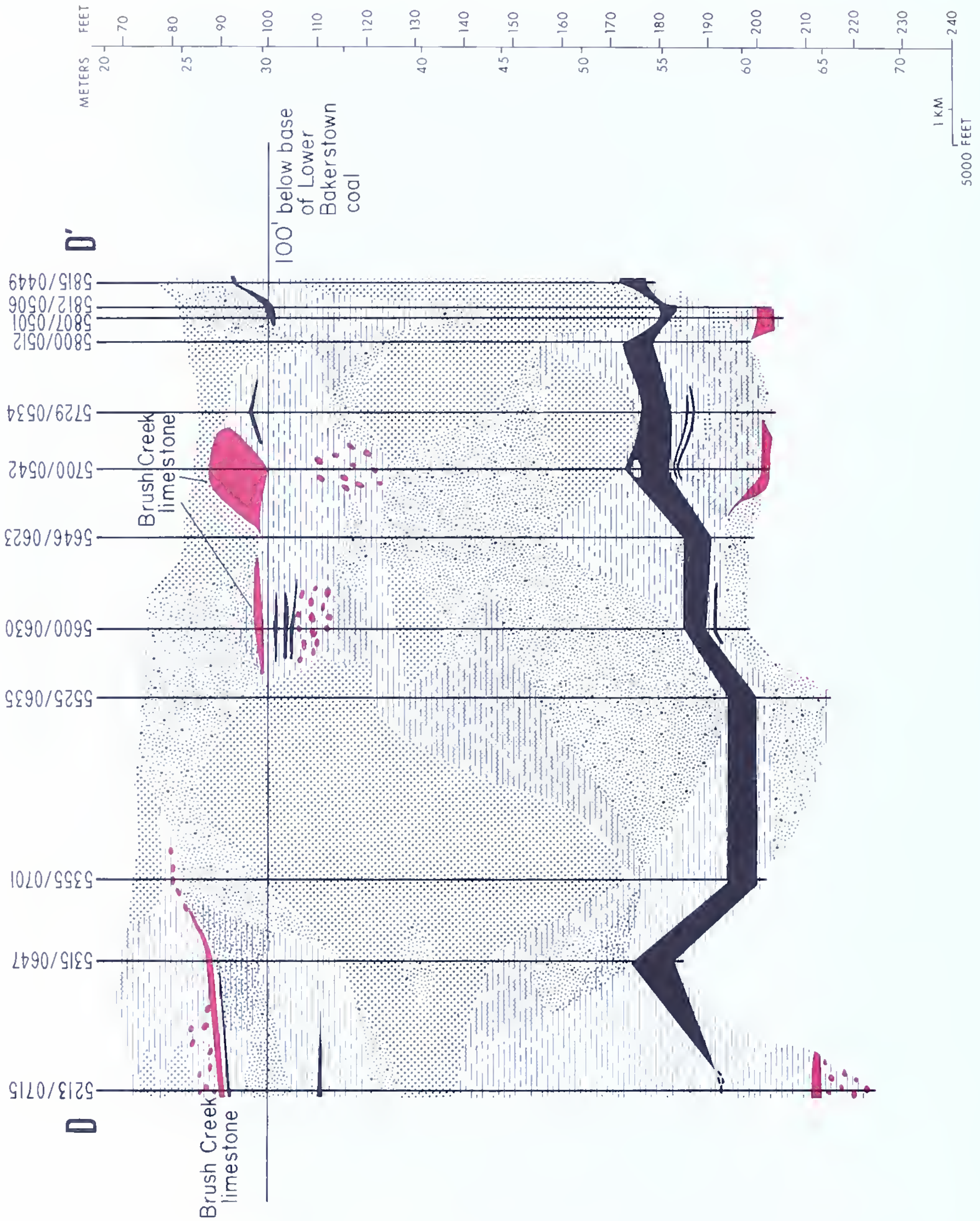
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5646/0623
5700/0542
5729/0534
5800/0512
5807/0501
5812/0506
5815/0449
Brush Creek limestone
Brush Creek limestone
100′ below base of Lower Bakerstown coal
METERS
20
25
30
40
45
50
55
60
65
70
FEET
70
80
90
100
110
120
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140
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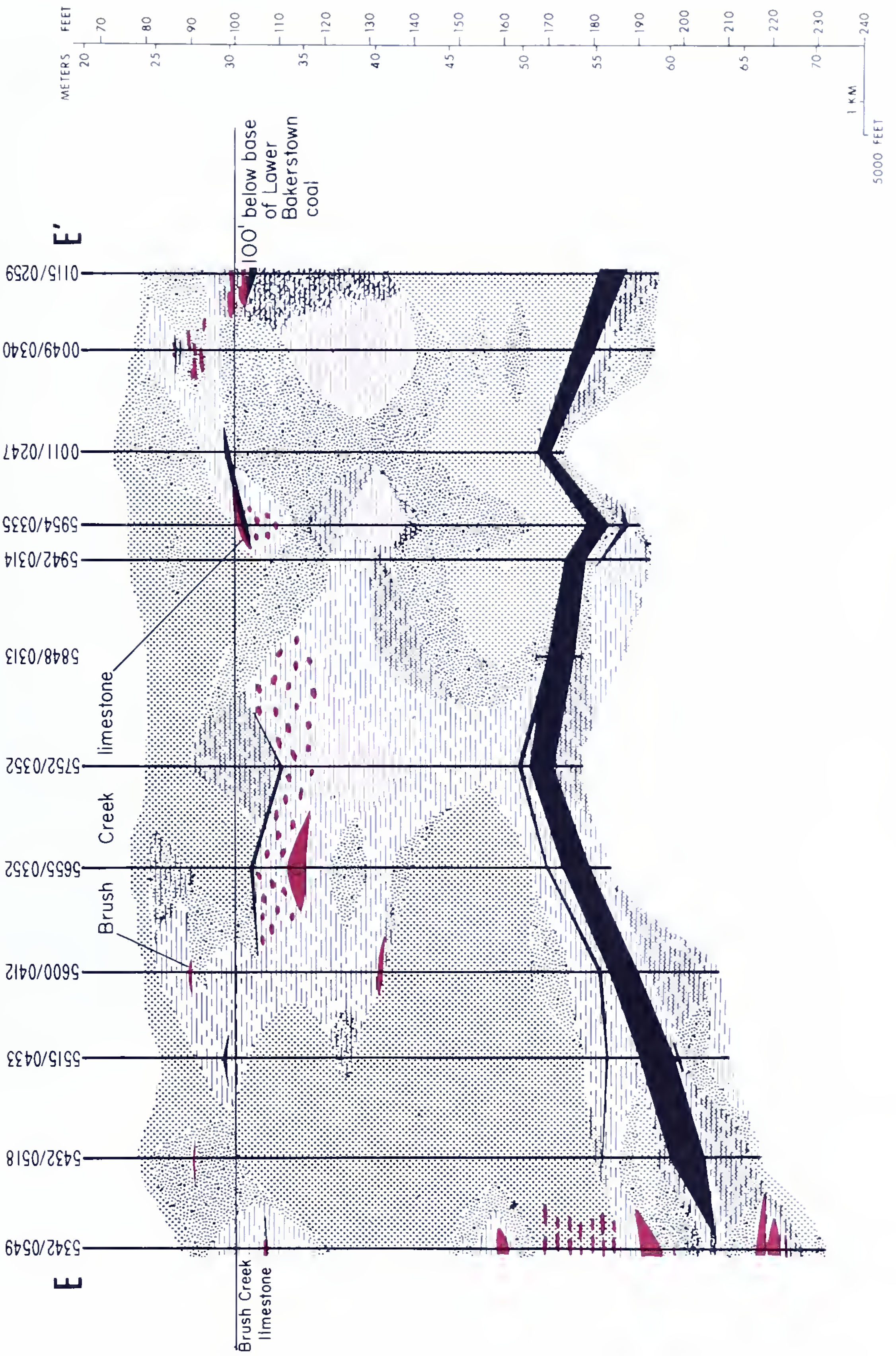
230
240
1 KM
5000 FEET



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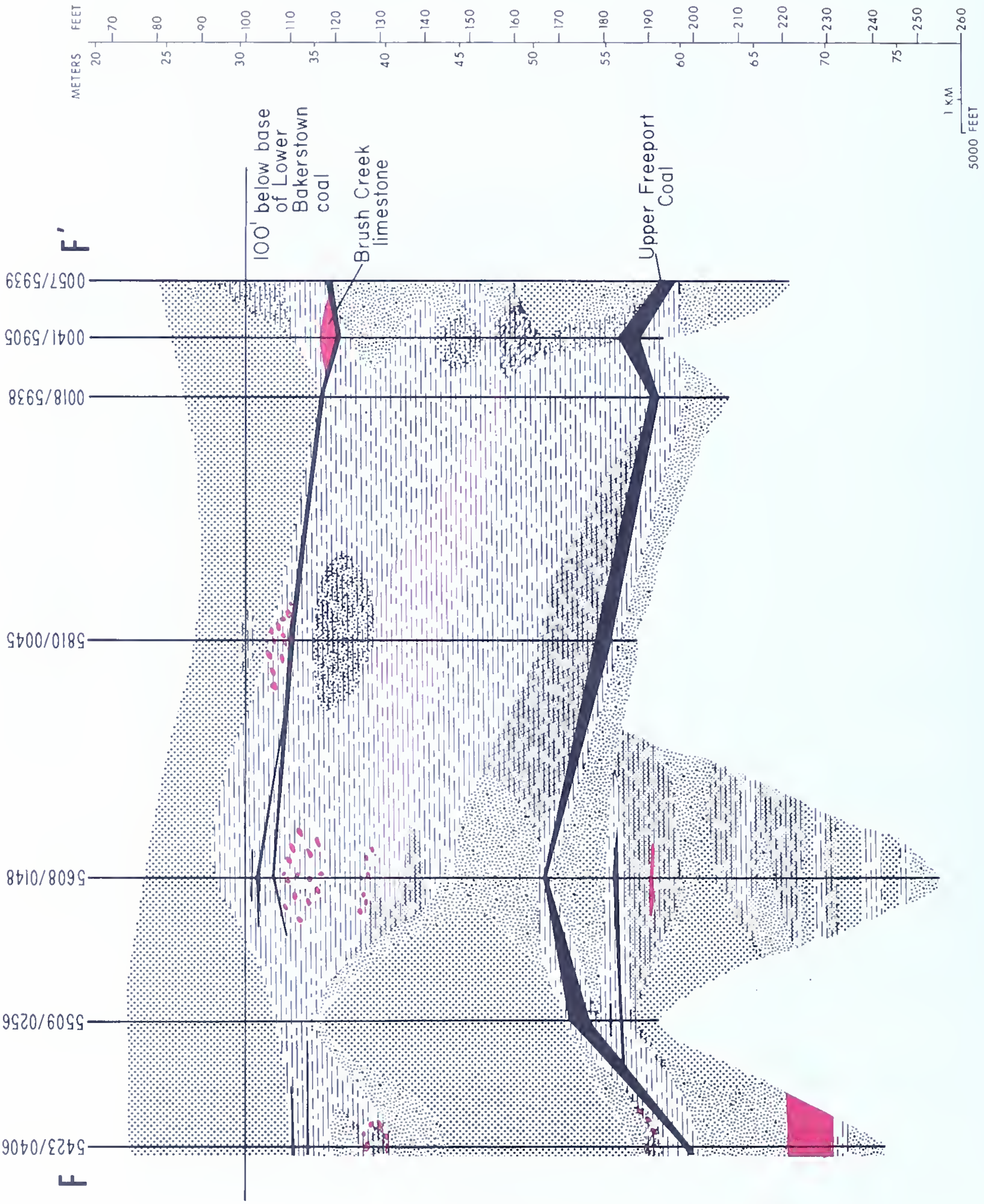
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F
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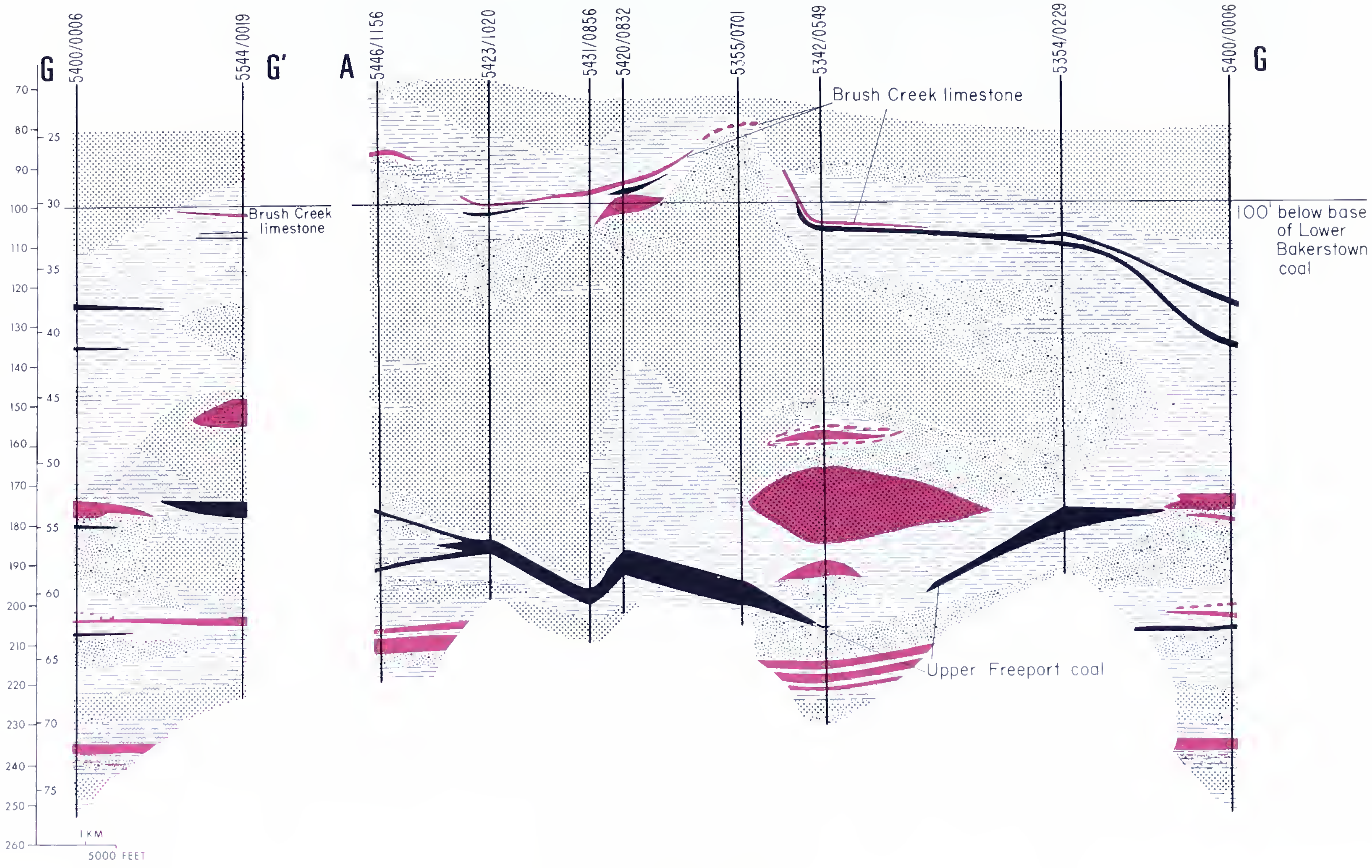
100' below base of Lower Bakerstown coal
Brush Creek limestone
Upper Freeport Coal
METERS
FEET
1 KM
5000 FEET



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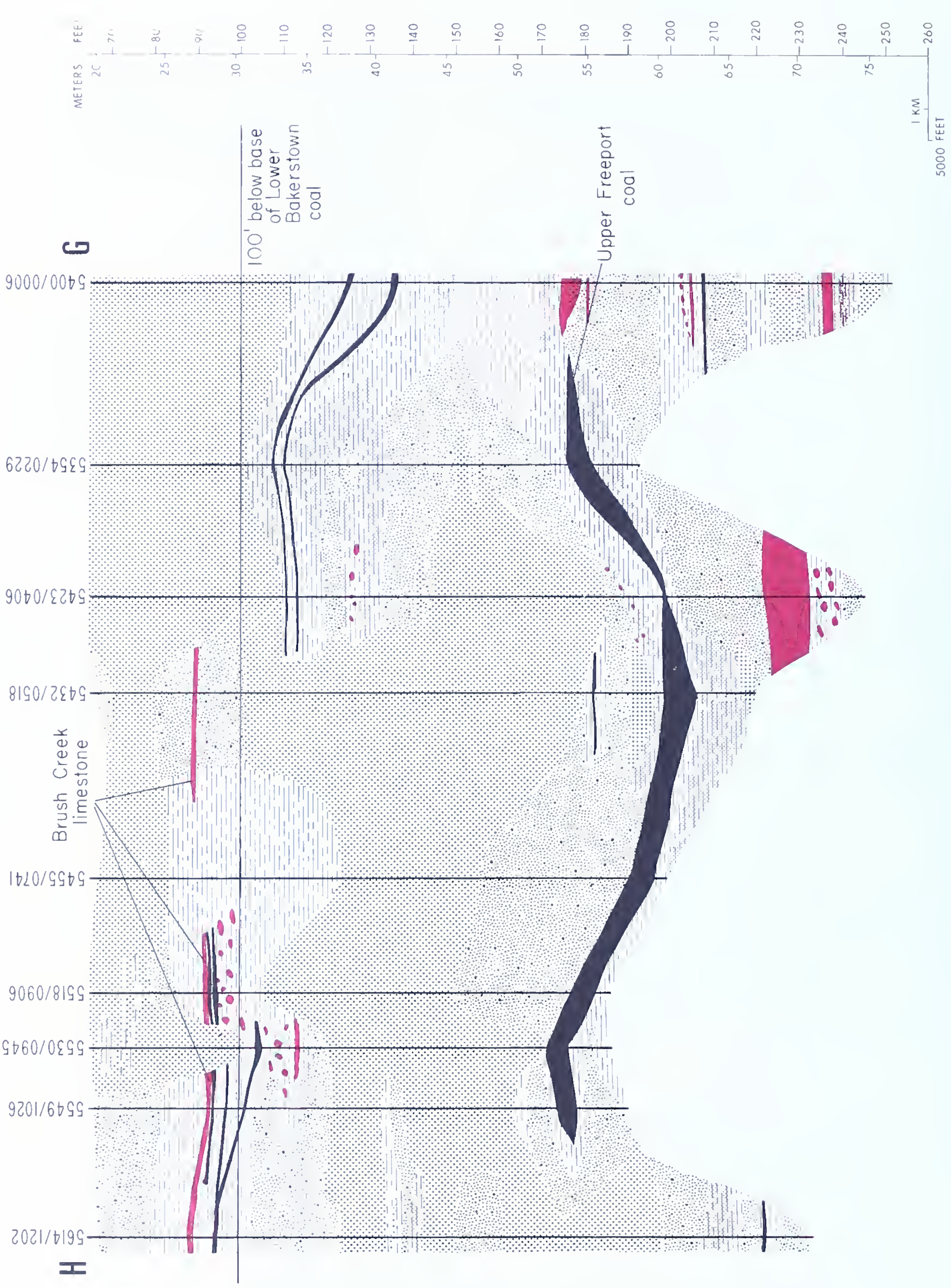
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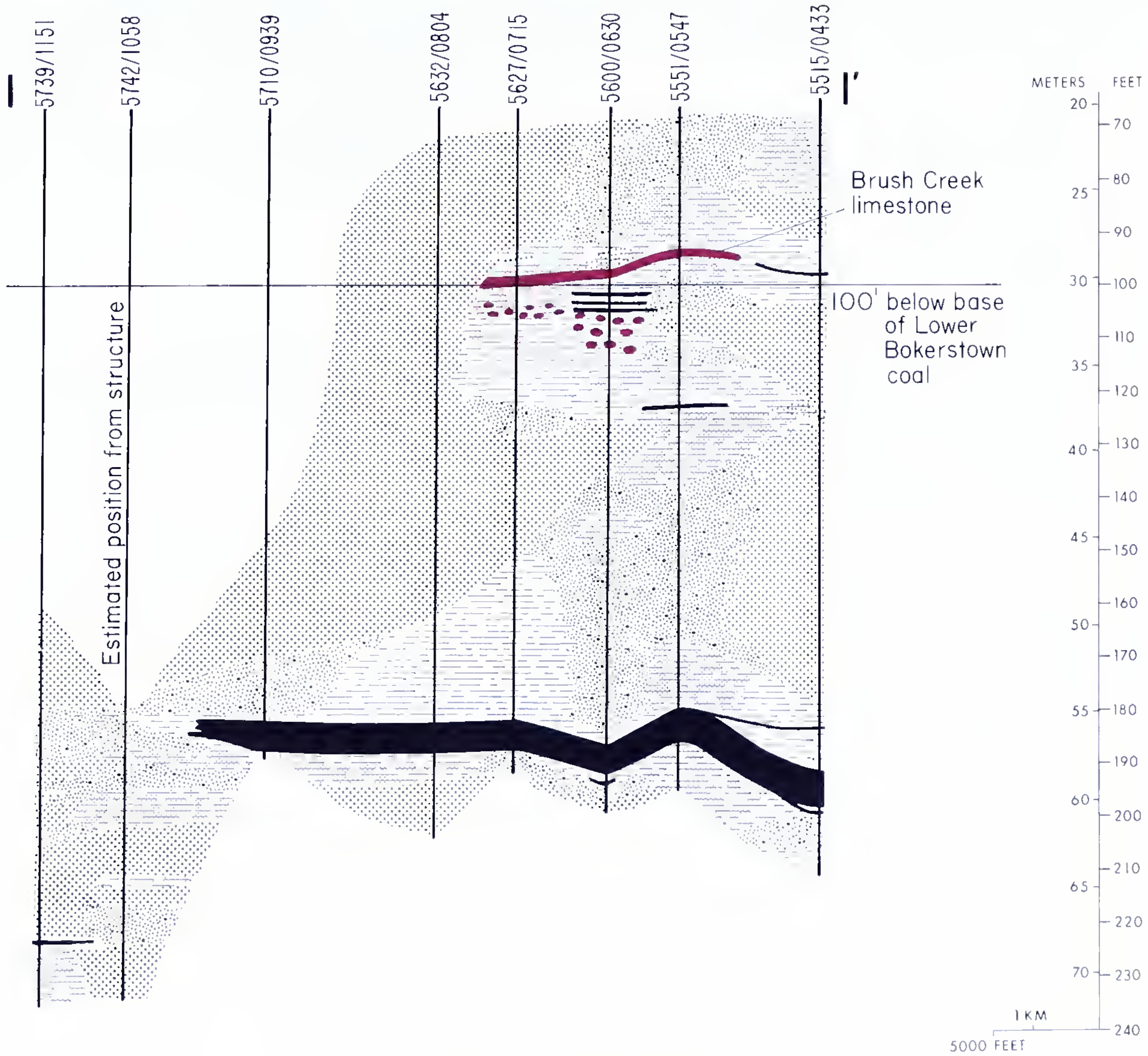
100' below base of Lower Bakerstown coal
Upper Freeport coal
Brush Creek limestone
METERS
FEET
1 KM
5000 FEET



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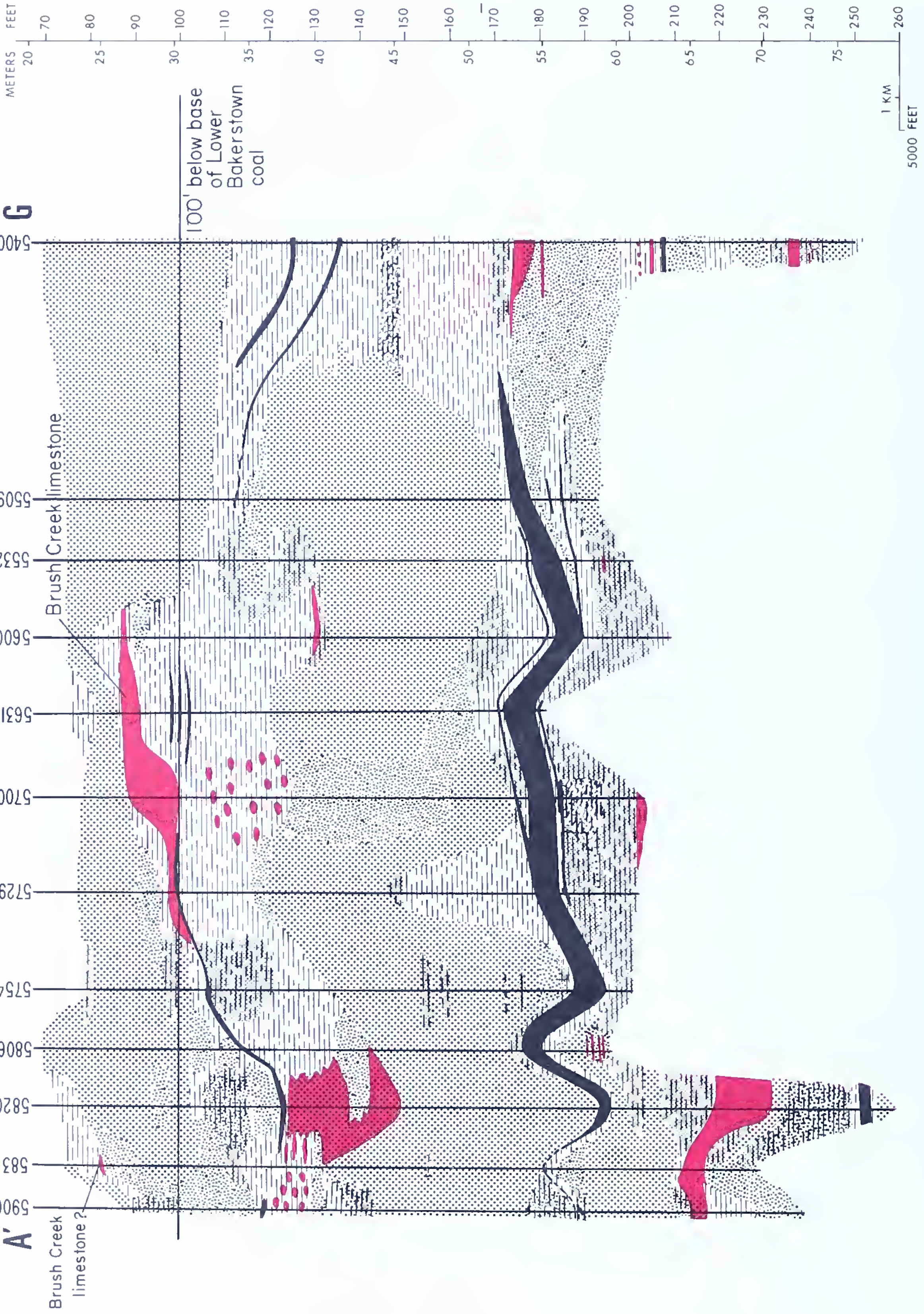
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5836/0946
5820/0907
5806/0828
5754/0753
5729/0643
5700/0542
5631/0453
5600/0412
5532/0330
5509/0256
5400/0006
Brush Creek limestone?
Brush Creek limestone
100' below base of Lower Bakerstown coal
METERS
FEET
1 KM
5000 FEET

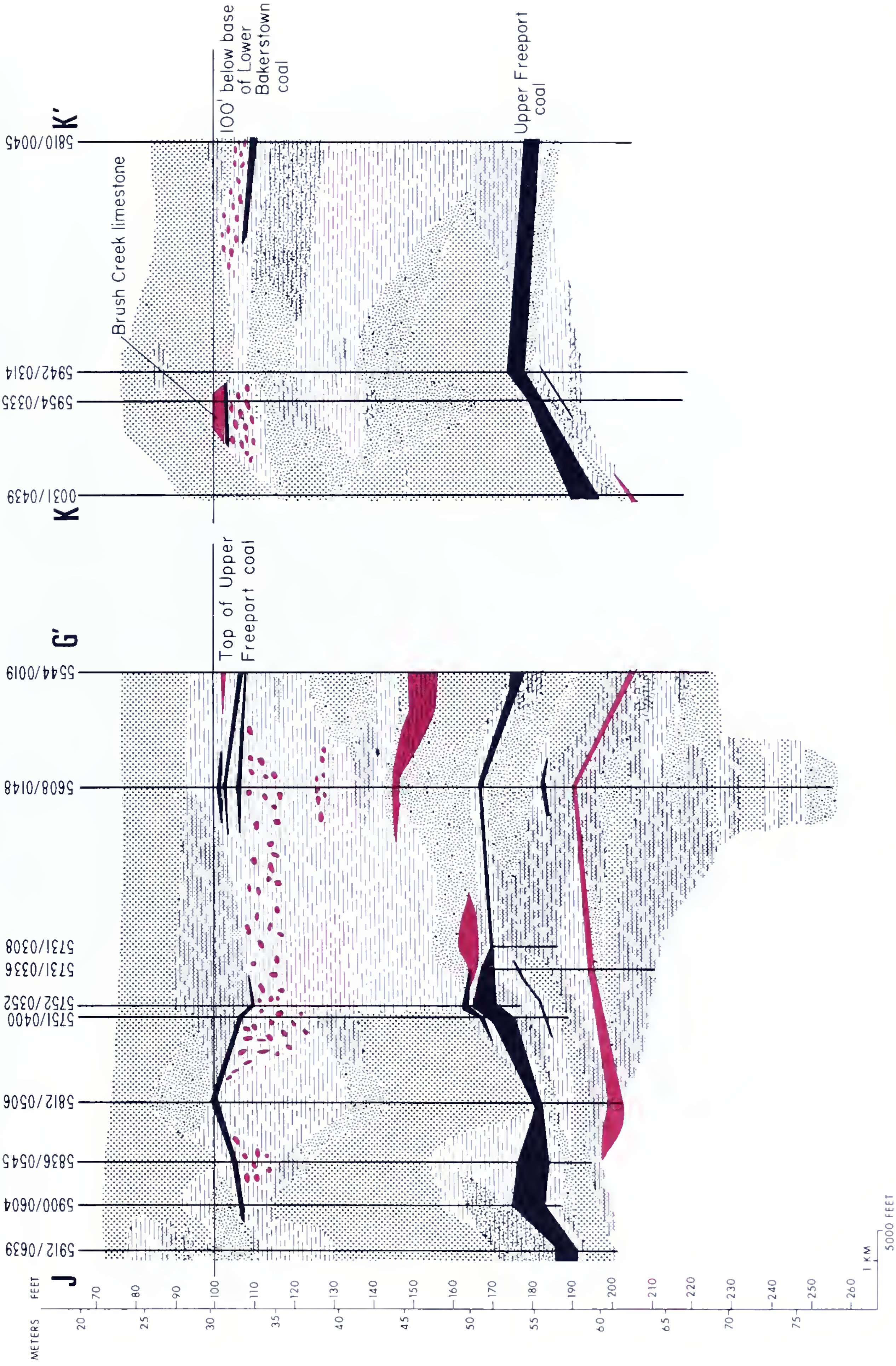


Figure 3. (Continued).

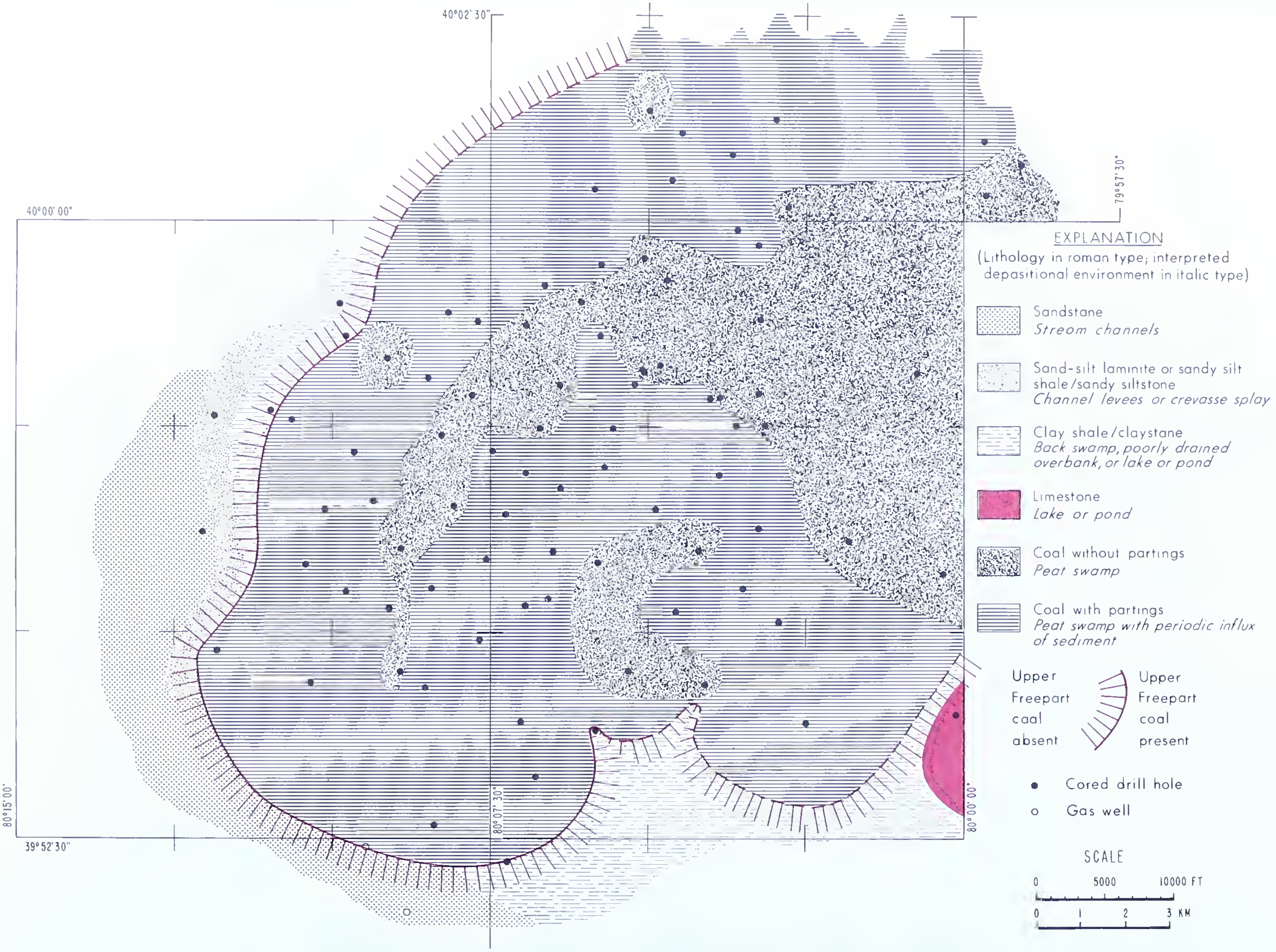

40°02′30″
40°00′00″
39°52′30″
79°57′30″
80°00′00″
80°07′30″
80°15′00″
EXPLANATION
(Lithology in roman type; interpreted depositional environment in italic type)
Sandstone
Stream channels
Sand-silt laminite or sandy silt shale/sandy siltstone
Channel levees or crevasse splay
Clay shale/claystone
Back swamp, poorly drained overbank, or lake or pond
Limestone
Lake or pond
Coal without partings
Peat swamp
Coal with partings
Peat swamp with periodic influx of sediment
Upper Freeport coal absent
Upper Freeport coal present
● Cored drill hole
○ Gas well
SCALE
0 5000 10000 FT
0 1 2 3 KM

Figure 4. Distribution of lithologies and interpretation of depositional environments at the Upper Freeport horizon.

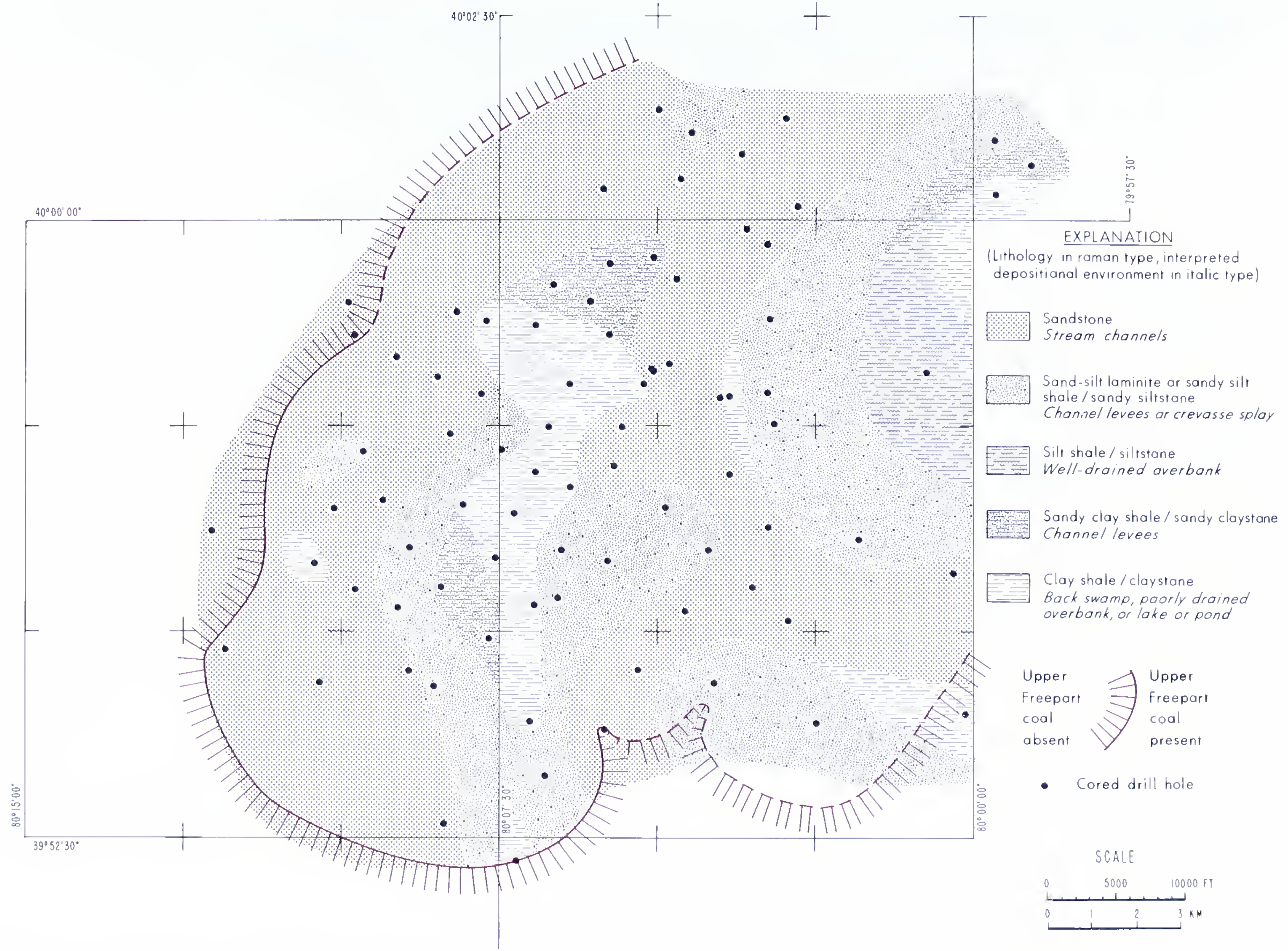

40°02' 30"
40°00' 00"
39°52' 30"
79°57' 30"
80°15' 00"
80°07' 30"
80°00' 00"
EXPLANATION
(Lithology in raman type, interpreted depositianal environment in italic type)
Sandstone
Stream channels
Sand-silt laminite ar sandy silt shale / sandy siltstane
Channel levees ar crevasse splay
Silt shale / siltstane
Well-drained averbank
Sandy clay shale / sandy claystane
Channel levees
Clay shale / claystane
Back swamp, paorly drained overbank, or lake or pond
Upper Freepart coal absent
Upper Freepart coal present
Cored drill hole
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 5. Distribution of lithologies and interpretation of depositional environments 10 feet (3 m) above the Upper Freeport coal.

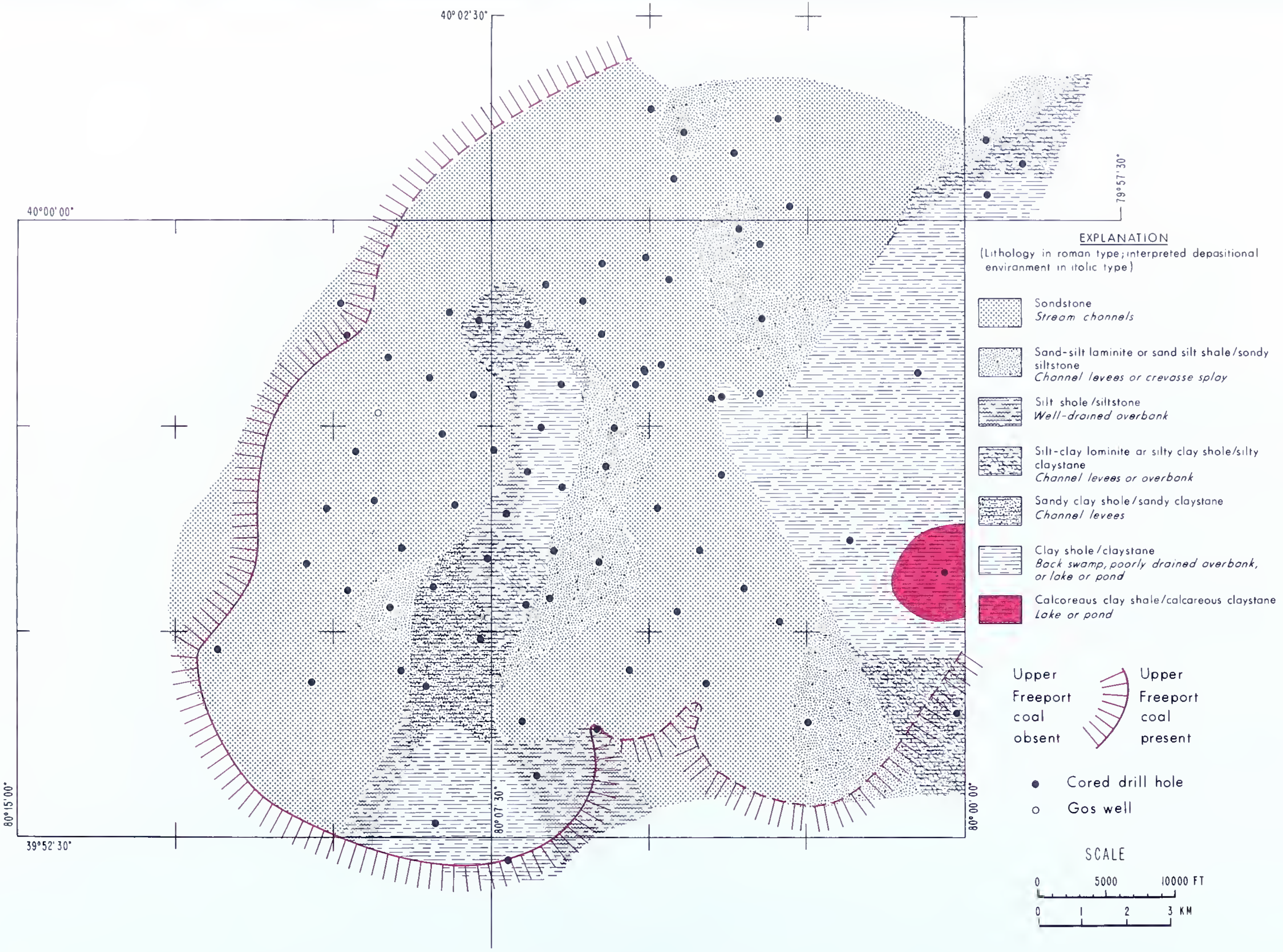

40°02'30"
40°00'00"
79°57'30"
39°52'30"
80°15'00"
80°07'30"
80°00'00"
EXPLANATION
(Lithology in roman type; interpreted depositional environment in italic type)
Sandstone
Stream channels
Sand-silt laminite or sand silt shale/sandy siltstone
Channel levees or crevasse splay
Silt shale/siltstone
Well-drained overbank
Silt-clay laminite or silty clay shale/silty claystone
Channel levees or overbank
Sandy clay shale/sandy claystone
Channel levees
Clay shale/claystone
Back swamp, poorly drained overbank, or lake or pond
Calcareous clay shale/calcareous claystone
Lake or pond
Upper Freeport coal absent
Upper Freeport coal present
Cored drill hole
Gas well
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 6. Distribution of lithologies and interpretation of depositional environments 25 feet (8 m) above the Upper Freeport coal.

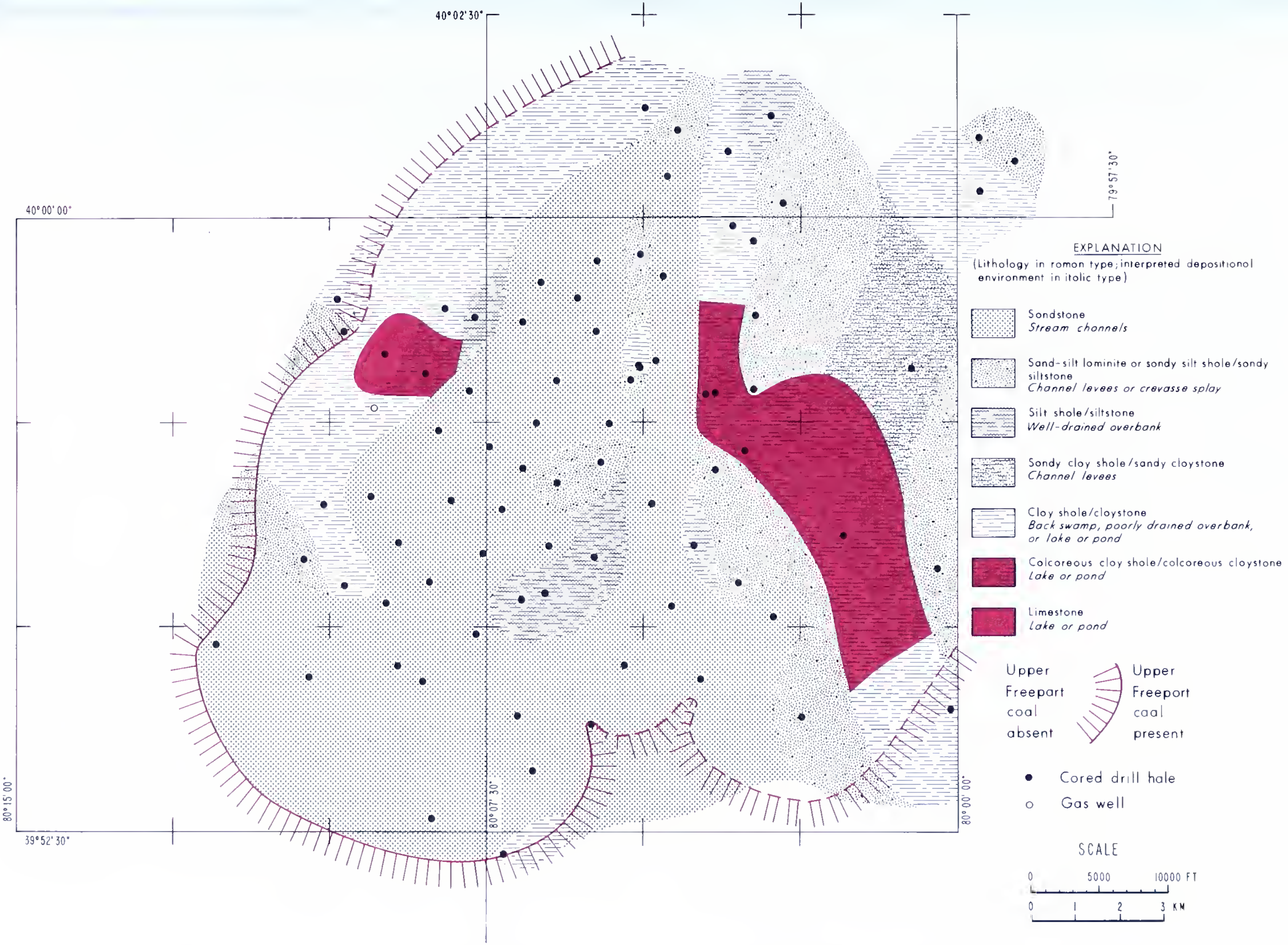

40°02'30"
40°00'00"
79°57'30"
80°15'00"
39°52'30"
80°07'30"
80°00'00"
EXPLANATION
(Lithology in roman type; interpreted depositional environment in italic type)
Sandstone
Stream channels
Sand-silt laminite or sandy silt shale/sandy siltstone
Channel levees or crevasse splay
Silt shale/siltstone
Well-drained overbank
Sandy clay shale/sandy claystone
Channel levees
Clay shale/claystone
Back swamp, poorly drained overbank, or lake or pond
Calcareous clay shale/calcareous claystone
Lake or pond
Limestone
Lake or pond
Upper Freeport coal absent
Upper Freeport coal present
Cored drill hole
Gas well
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 7. Distribution of lithologies and interpretation of depositional environments 50 feet (15 m) above the Upper Freeport coal.

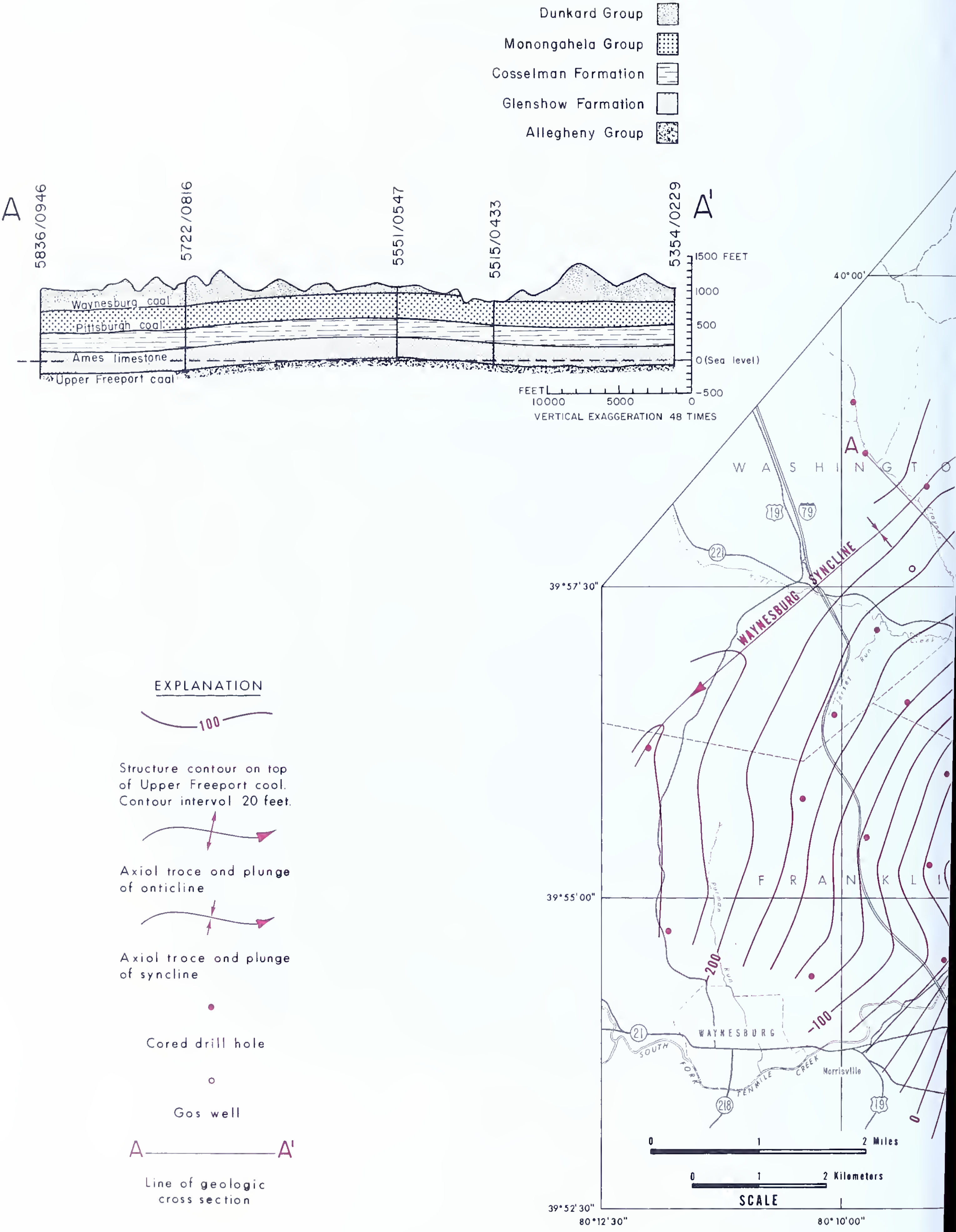
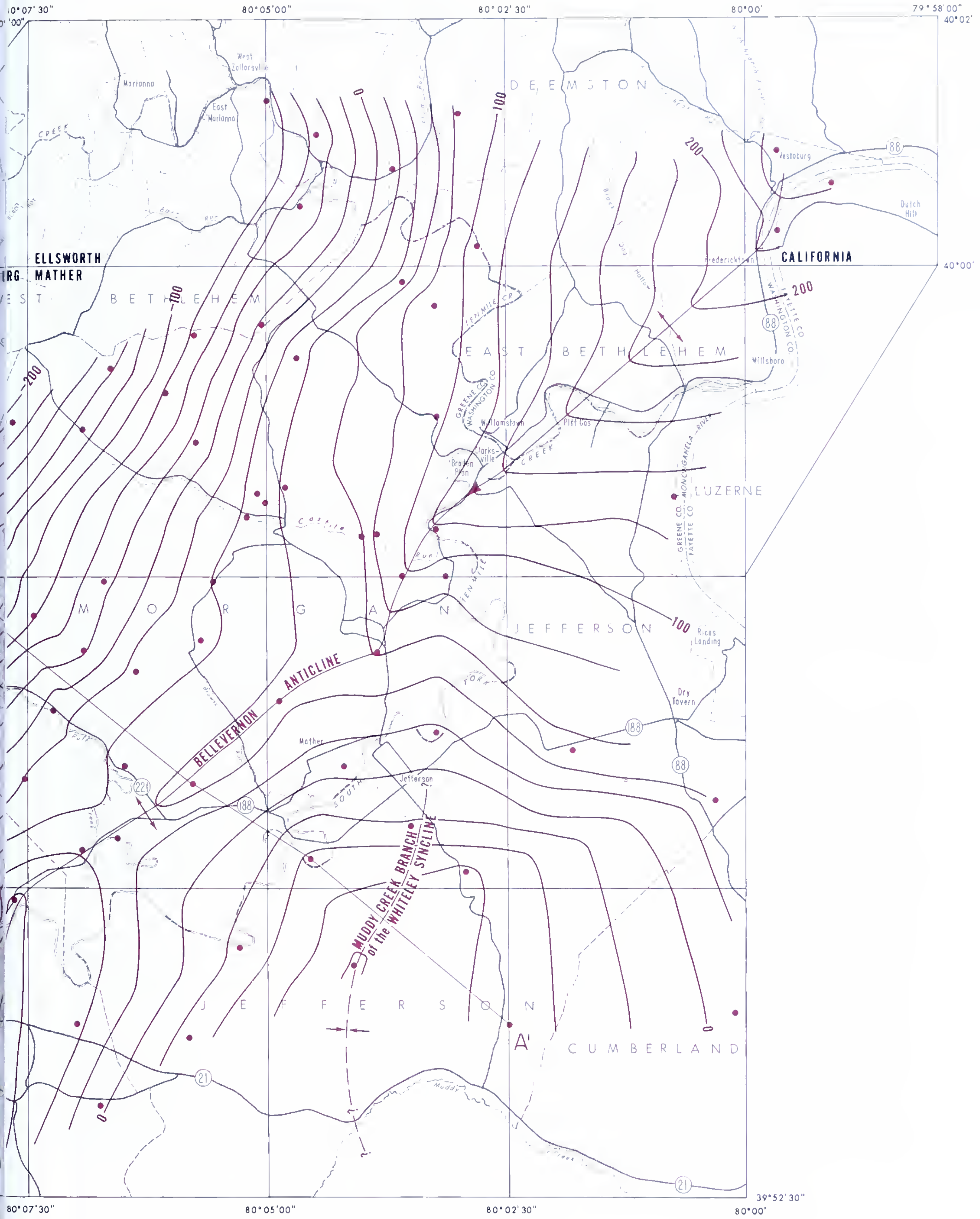


Figure 8. Structure-cont



he Upper Freeport coal.

cm) thick and covers a roughly oval area about 9 miles (14 km) wide in an east-west direction and 12 miles (19 km) long in a north-south direction (Figure 9). The coal thins or pinches out at the margins of this area (Figure 3A, E, F, I, J, and K). Its maximum thickness is 104 inches (264 cm). It has a very definite western and southwestern limit where its thickness goes from 60 to 0 inches (152 to 0 cm) within a 0.5- to 1.5-mile (0.8- to 2.4-km) distance. This situation is assumed to also exist in the northern part of the study area, even though data are scarcer there and none exist in the no-coal area. This assumption is based on some evidence of rapid northwestward thinning of the coal. The coal also thins in the eastern and southeastern portion of the study area; however, no clear limits or trends are apparent. Several no-coal and thin-coal areas are present in the southeast, but these are interspersed with coal up to 85 inches (216 cm) thick. Limited data suggest that the coal may not pinch out to the northeast, but data are too sparse for confident prediction.

Internal Organization

The analysis of the Upper Freeport coal is based on detailed stratigraphic cross sections constructed to represent as much of the study area as possible (Figure 10).

Over a substantial part of the area the coal contains no recorded partings, but clay shale partings are present elsewhere near the base and top of the main seam. Some clay shale partings are also recorded near the middle of the coal at a few locations. Definite correlation of individual partings was impossible because of their variability in number and position. Nevertheless, an attempt was made to show the distribution of partings that presumably were deposited in the peat swamp at about the same time. This was done by dividing them into three groups: (1) partings near the base of the coal; (2) partings near the top of the coal; and (3) the few partings in the middle of the coal (Figures 11, 12, and 13). The partings near the base of the coal are most widespread, covering nearly the entire swamp. Knowledge of the distribution of the few partings in the middle of the coal, and of the upper partings, is more limited. They appear to have been deposited along the western limit of the coal body and within a roughly north-south-trending area in the central and western part of the Mather quadrangle. These partings are generally thin and are present only over part of the area of thick coal. They should not seriously affect the economic value of the coal.

A thin, discontinuous coal is present below the Upper Freeport coal (Figure 14). To the west it merges with the Upper Freeport, whereas to the east the coal is as much as 15.7 feet (4.8 m) below the main coal. Thin sandstone lenses are locally present between the Upper Freeport and the lower coal in the larger intervals in the east.

There is also a local split above the Upper Freeport extending northward from the south-central part of the Mather quadrangle (Figures 3E and 15). The areal distribution of this split corresponds roughly with the distribution of the middle and upper partings in the Upper Freeport coal in the Mather quadrangle. The rock in the interval between the main coal and the split is thicker and coarser in the south and becomes finer grained as the split converges with the Upper Freeport coal to the north. The rock type in this interval varies from sandstone and siltstone in the south to claystone in the north.

Coal cutouts, or places where an ancient stream channel cut down through the peat swamp, are important features to recognize in areas to be deep mined. These channels cutting into the coal were generally filled with sand (now sandstone). In places where the channels had cut deeply into or completely through the coal, these sand-filled cutouts are a serious obstacle to coal mining. However, if these cutouts are recognized and located during exploration,

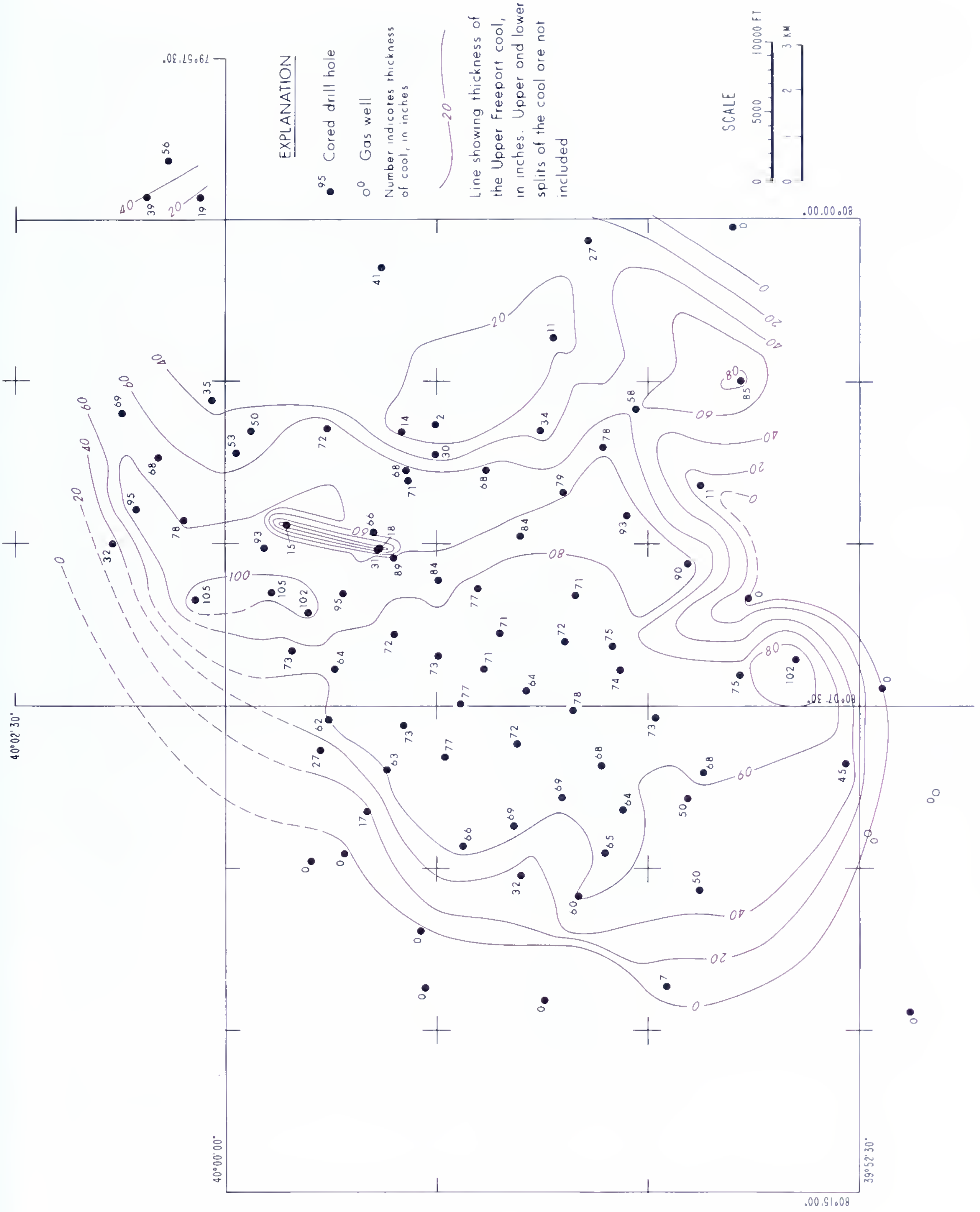
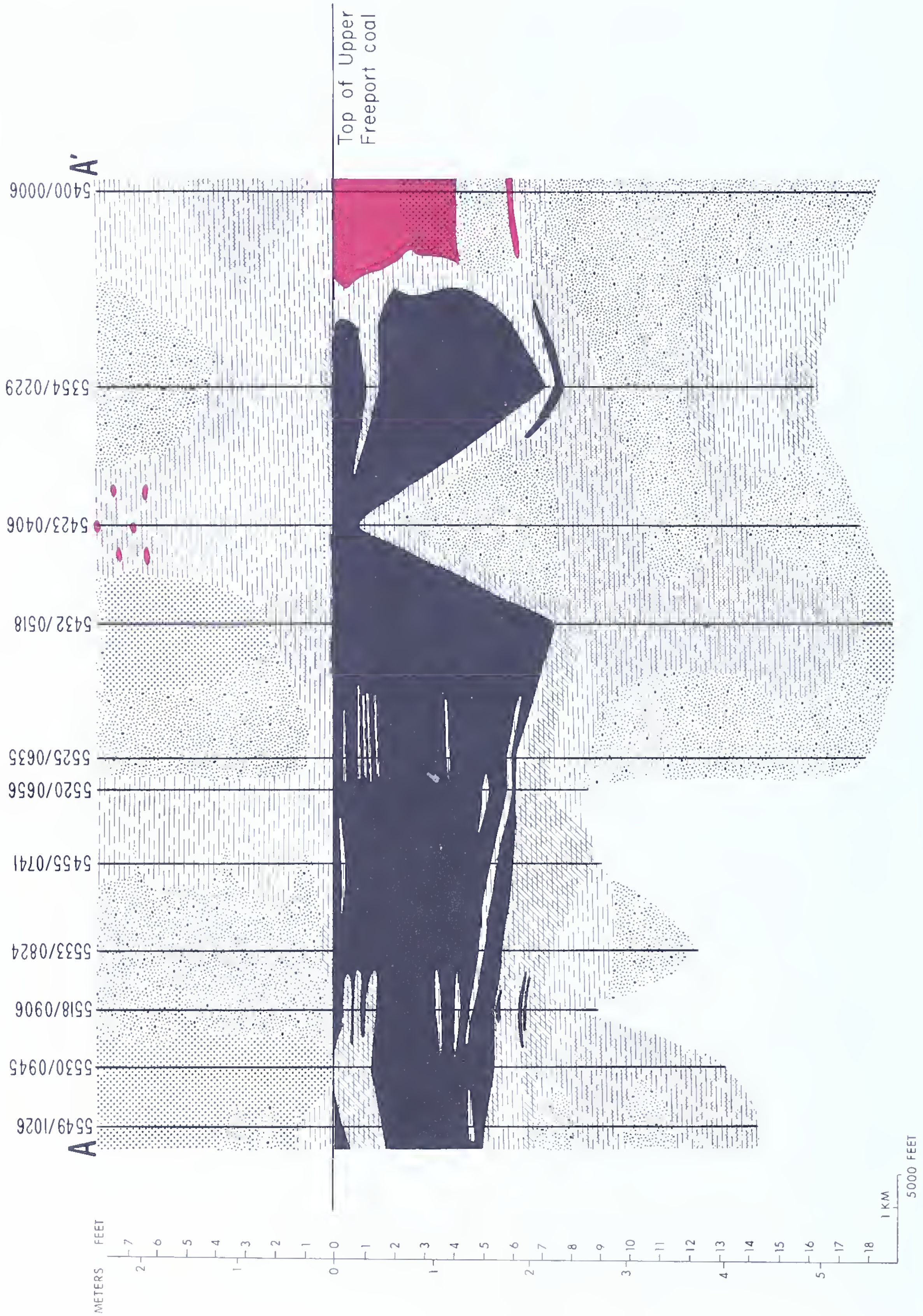

EXPLANATION
95 Cored drill hole
0 Gas well
Number indicates thickness of coal, in inches
20 Line showing thickness of the Upper Freeport coal, in inches. Upper and lower splits of the coal are not included
SCALE
0
5000
10000 FT
0
1
2
3 KM
79°57'30"
80°00'00"
80°07'30"
80°15'00"
40°02'30"
40°00'00"
39°52'30"

Figure 9. Thickness map of the Upper Freeport coal.


Top of Upper Freeport coal
A′
5400/0006
5354/0229
5423/0406
5432/0518
5525/0635
5520/0656
5455/0741
5533/0824
5518/0906
5530/0945
5549/1026
A
FEET
7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
METERS
2 1 0 1 2 3 4 5
1 KM
5000 FEET

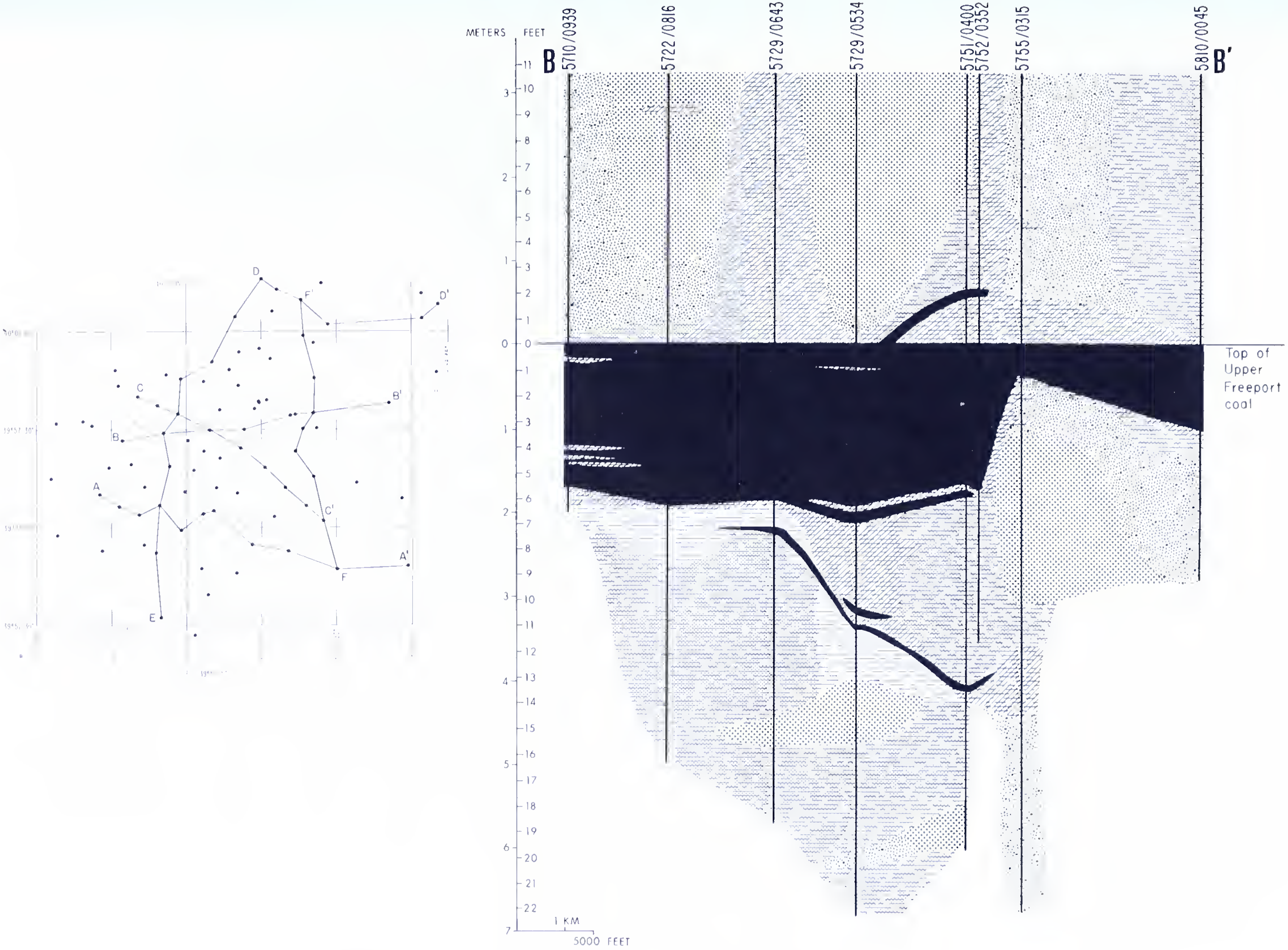
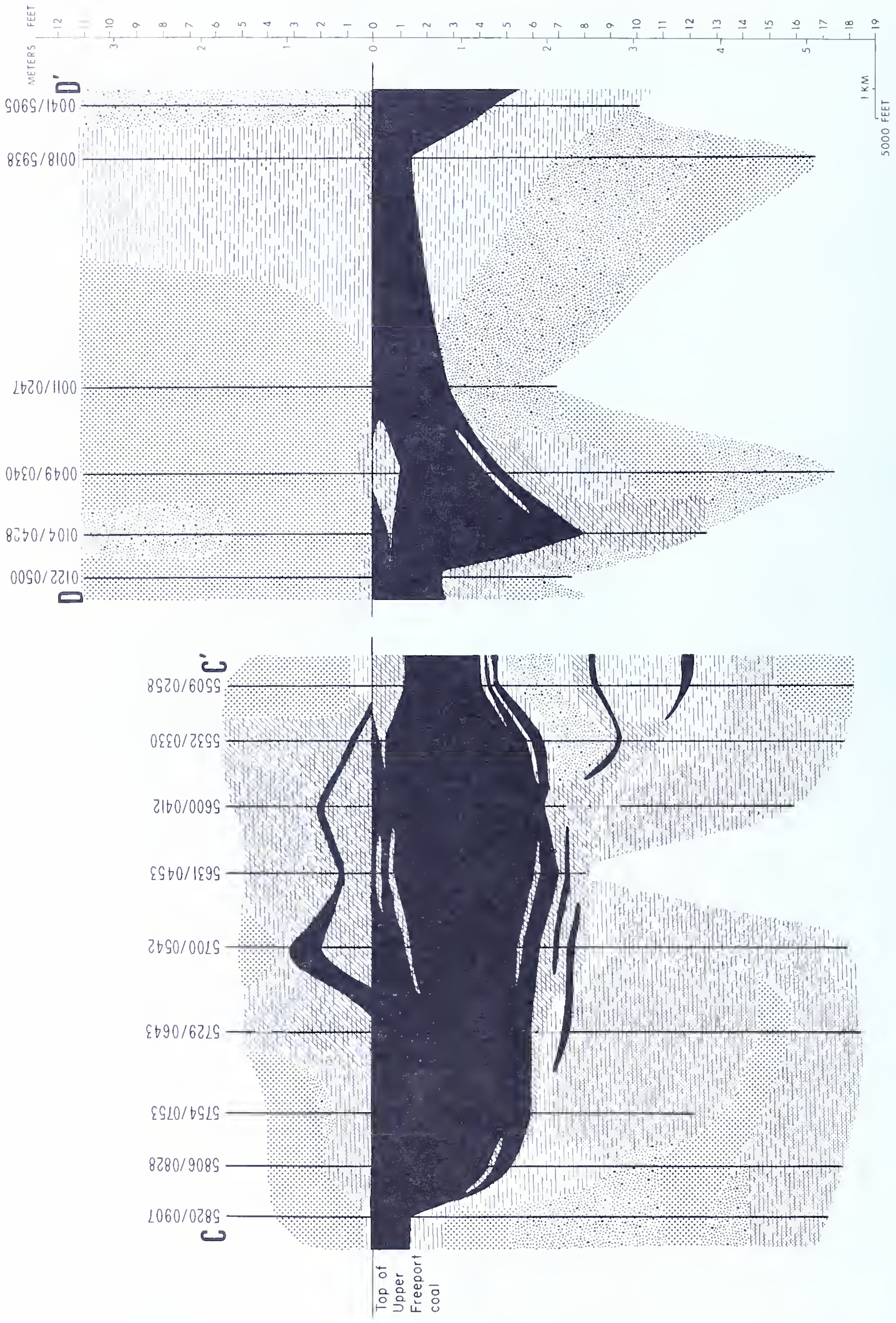


Figure 10. Stratigraphic cross sections of the Upper Freeport coal.


D′
0041/5905
0018/5938
0011/0247
0049/0340
0104/0428
0122/0500
D
C′
5509/0258
5532/0330
5600/0412
5631/0453
5700/0542
5729/0643
5754/0753
5806/0828
5820/0907
C
Top of Upper Freeport coal
METERS
FEET
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
1 KM
5000 FEET

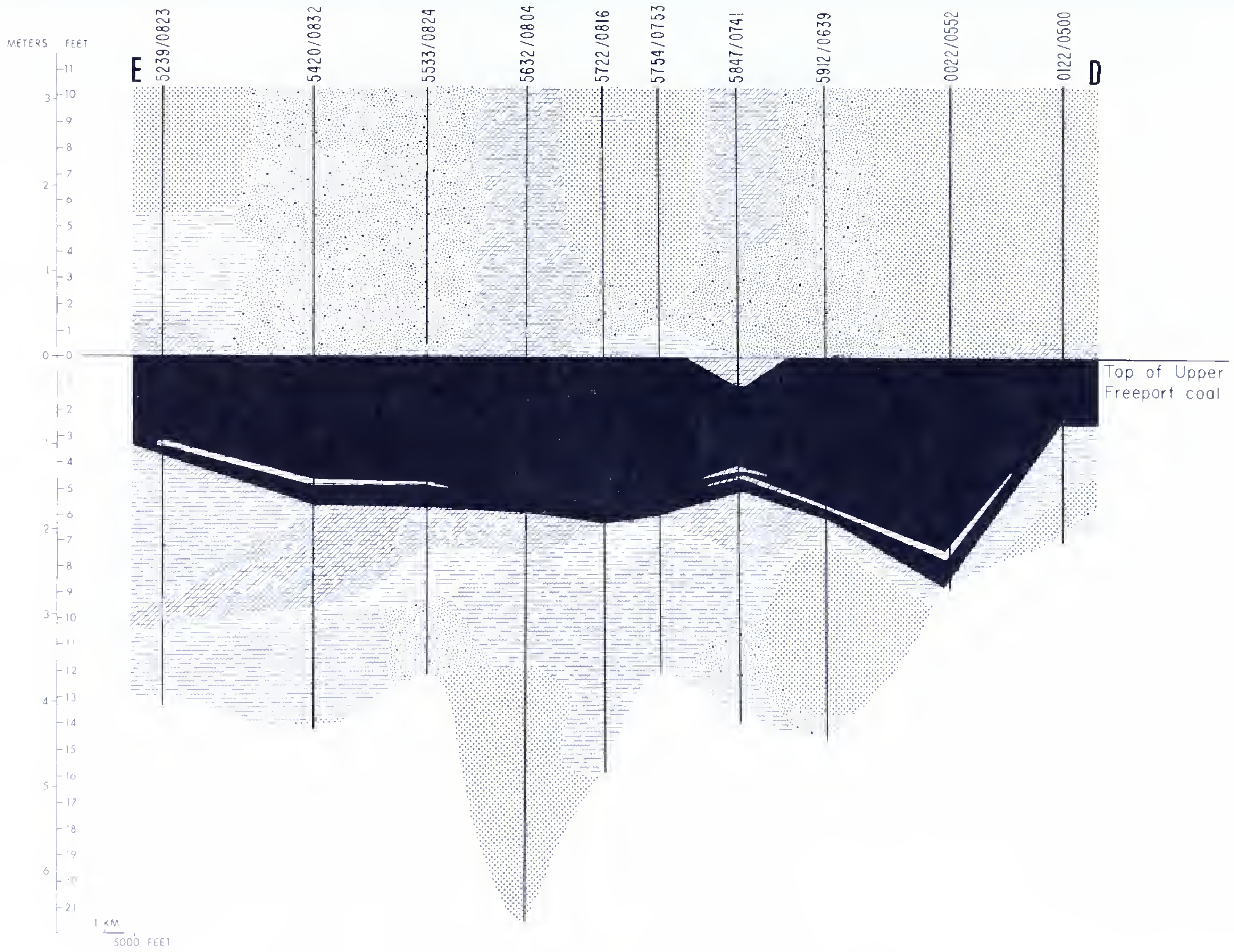


Figure 10. (*Continued*).

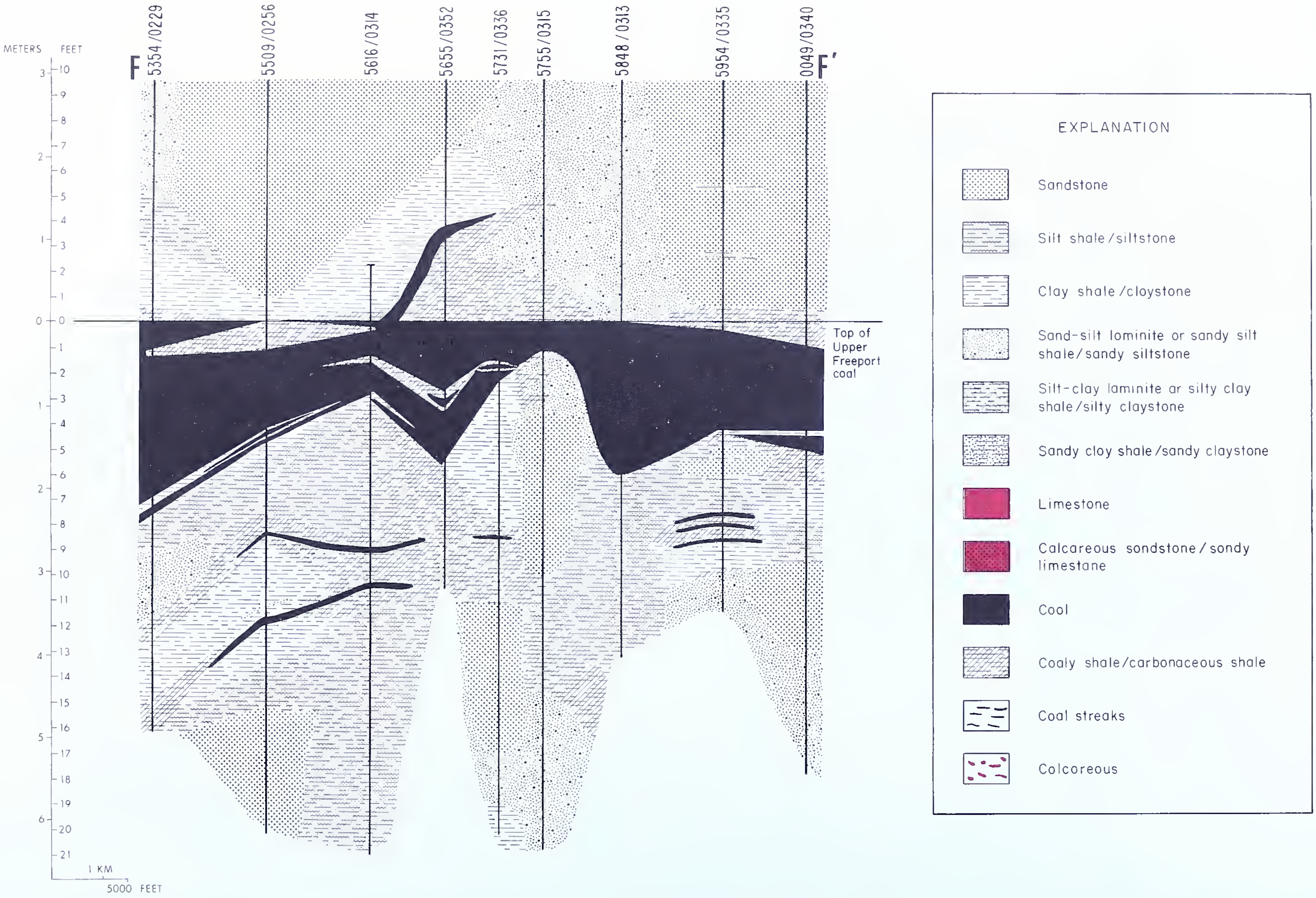


Figure 10. *(Continued)*.

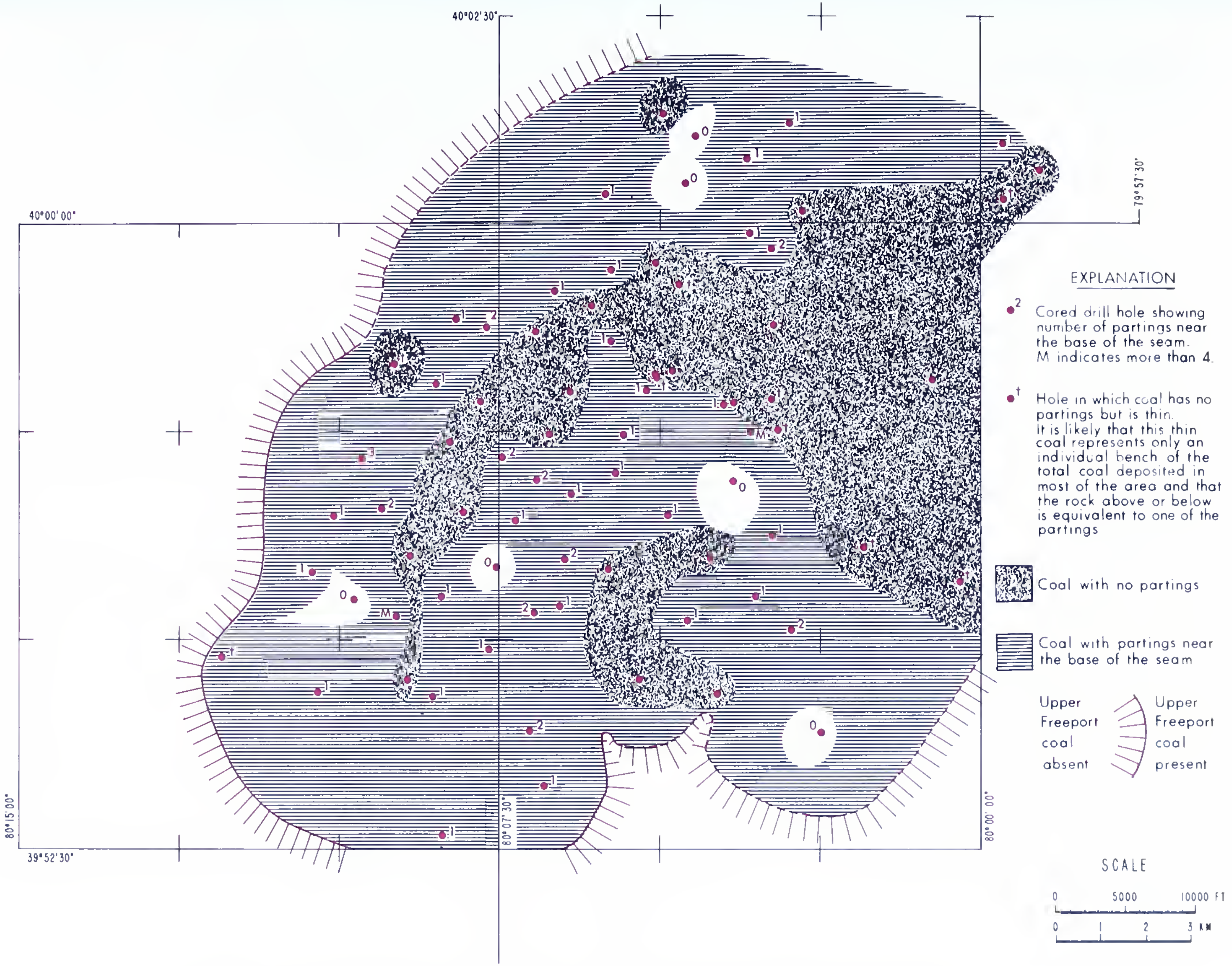

40°02'30"
40°00'00"
79°57'30"
80°15'00"
39°52'30"
80°07'30"
80°00'00"
EXPLANATION
Cored drill hole showing number of partings near the base of the seam. M indicates more than 4.
Hole in which coal has no partings but is thin. It is likely that this thin coal represents only an individual bench of the total coal deposited in most of the area and that the rock above or below is equivalent to one of the partings
Coal with no partings
Coal with partings near the base of the seam
Upper Freeport coal absent
Upper Freeport coal present
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 11. Distribution of partings near the base of the Upper Freeport coal.

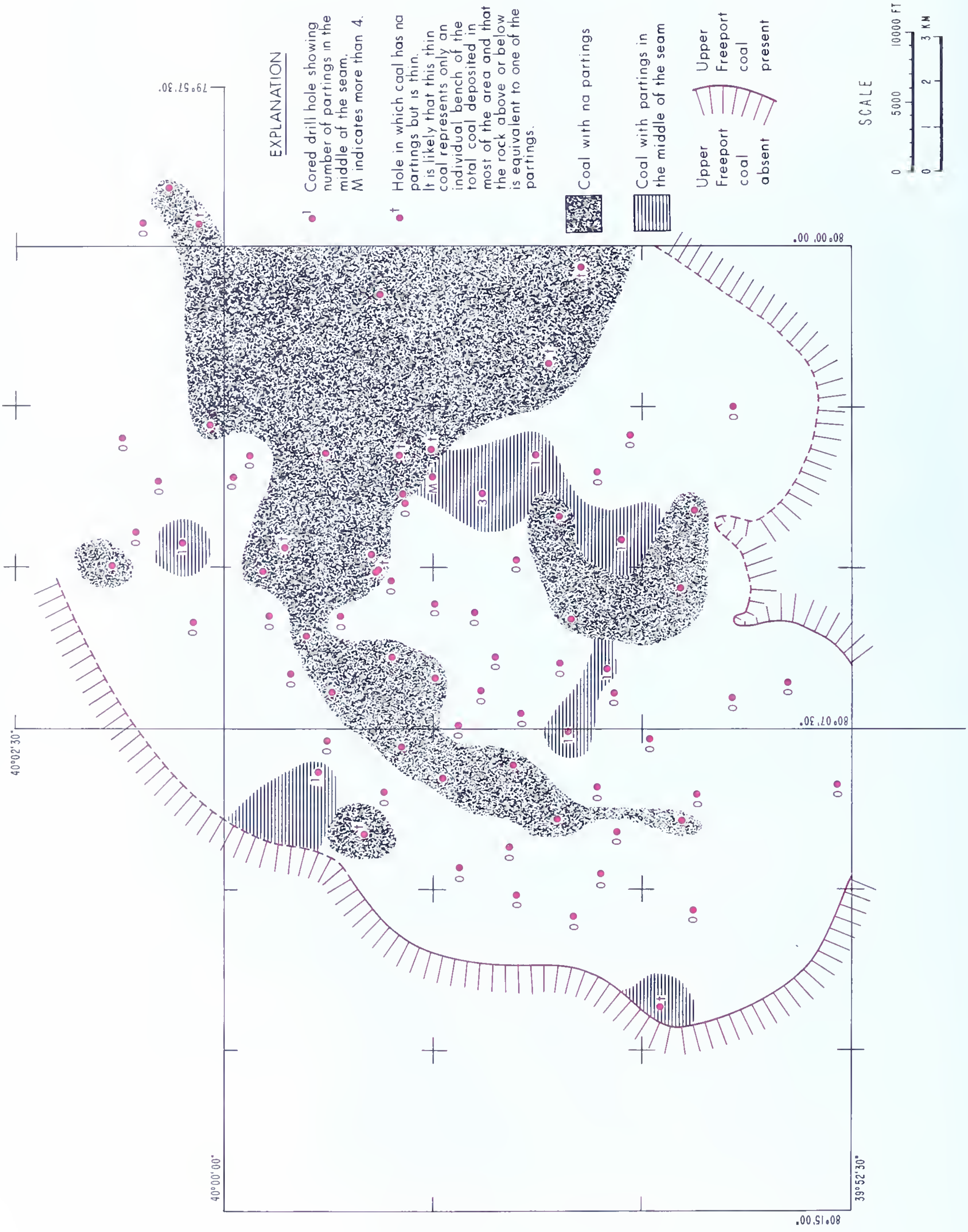

EXPLANATION
1 ● Cored drill hole showing number of partings in the middle of the seam. M indicates more than 4.
t ● Hole in which coal has no partings but is thin. It is likely that this thin coal represents only an individual bench of the total coal deposited in most of the area and that the rock above or below is equivalent to one of the partings.
Coal with no partings
Coal with partings in the middle of the seam
Upper Freeport coal absent
Upper Freeport coal present
SCALE
0
5000
10000 FT
0
1
2
3 KM
79°57'30"
80°00'00"
80°07'30"
80°15'00"
40°02'30"
40°00'00"
39°52'30"

Figure 12. Distribution of partings in the middle of the Upper Freeport coal.

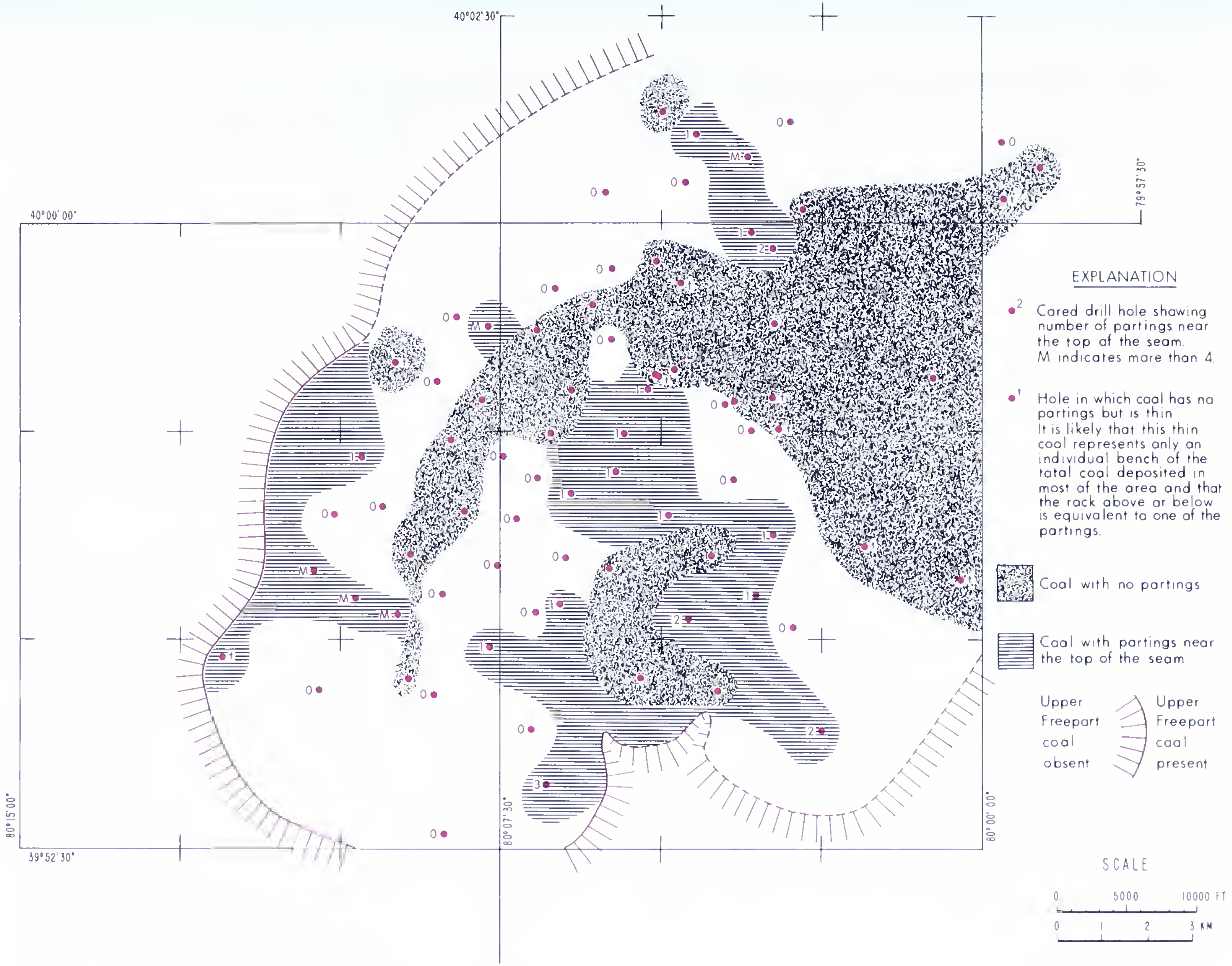

40°02'30"
40°00'00"
39°52'30"
79°57'30"
80°00'00"
80°07'30"
80°15'00"
EXPLANATION
2 Cored drill hole showing number of partings near the top of the seam. M indicates more than 4.
t Hole in which coal has no partings but is thin. It is likely that this thin coal represents only an individual bench of the total coal deposited in most of the area and that the rock above or below is equivalent to one of the partings.
Coal with no partings
Coal with partings near the top of the seam
Upper Freeport coal absent
Upper Freeport coal present
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 13. Distribution of partings near the top of the Upper Freeport coal.

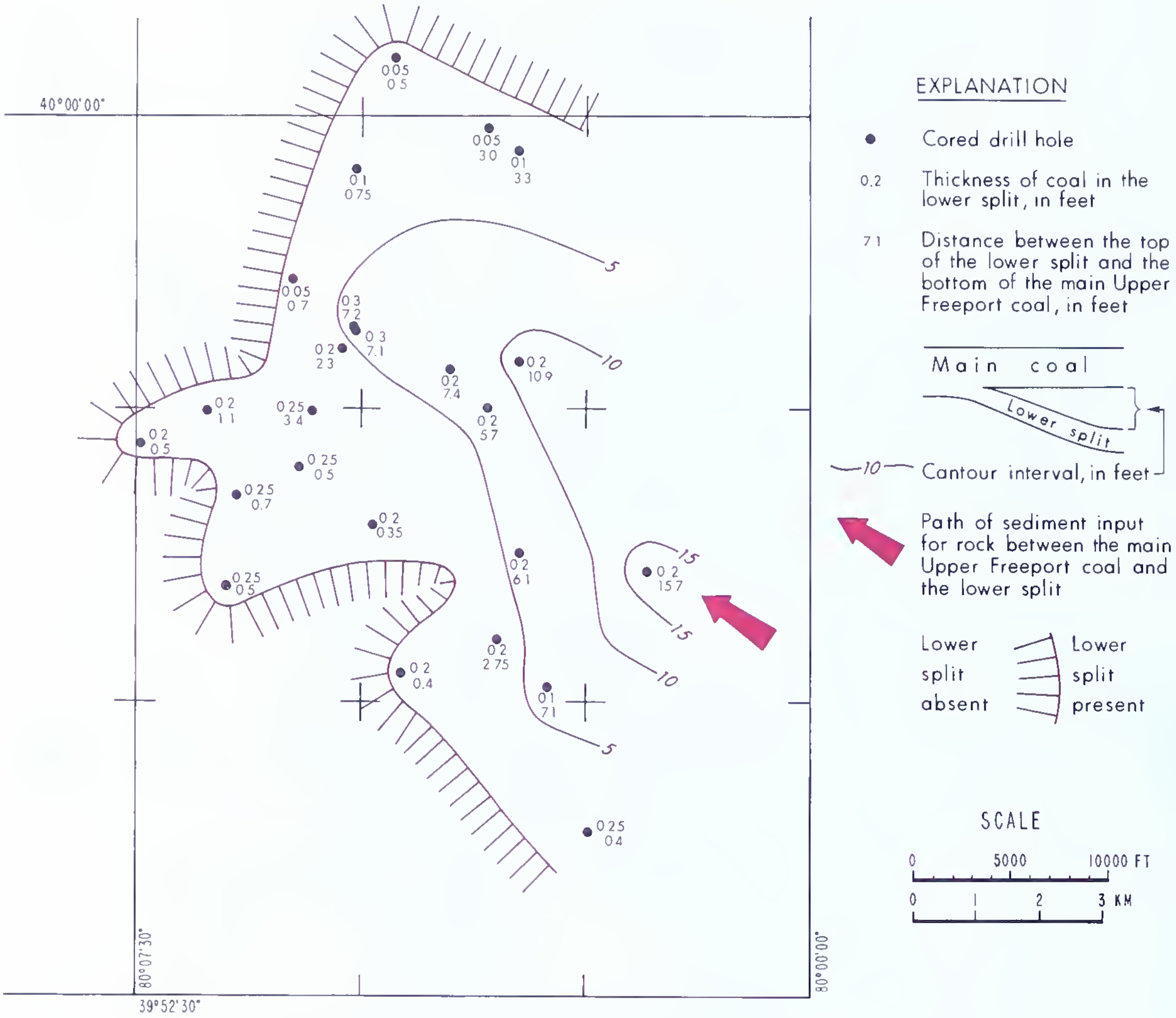

40°00'00"
80°07'30"
80°00'00"
39°52'30"
005
05
005
30
01
33
01
075
005
07
03
72
03
71
02
23
02
74
02
109
02
57
02
11
025
34
02
05
025
05
025
07
02
035
02
61
02
157
025
05
02
275
02
04
01
71
025
04
5
10
15
EXPLANATION
Cored drill hole
0.2 Thickness of coal in the lower split, in feet
7 1 Distance between the top of the lower split and the bottom of the main Upper Freeport coal, in feet
Main coal
Lower split
10 Contour interval, in feet
Path of sediment input for rock between the main Upper Freeport coal and the lower split
Lower split absent
Lower split present
SCALE
0
5000
10000 FT
0
1
2
3 KM

Figure 14. Distribution of the lower split of the Upper Freeport coal.

the mine can be planned so that they are avoided. The Upper Freeport coal appears to be partially removed by channel downcutting in the northern part of the Mather quadrangle about 2 miles (3 km) west of the town of Clarksville. Data are limited, but the presence of a thick, elongate sandstone above the coal in this area (Figures 5 and 18), the apparent elongate shape of the thinned coal area, and the fact that sandstone is either directly on the coal or separated from it by a thin sandy shale bed suggest a possible coal cutout. Another similar cutout may exist in the same area, overlain by the north-south-trending elongate sandstone body. When situations such as this are encountered, additional drilling should be conducted prior to mine development.

Boundaries of the Coal Body

The Upper Freeport coal in this area is replaced laterally by a variety of rock types (Figure 3). In the southwestern part of the Mather quadrangle, the coal grades into a carbonaceous claystone (Figure 3E). To the west, correlation is less certain and the Upper Freeport cannot be correlated with a single noncoal bed because the interval consists mostly of sand-

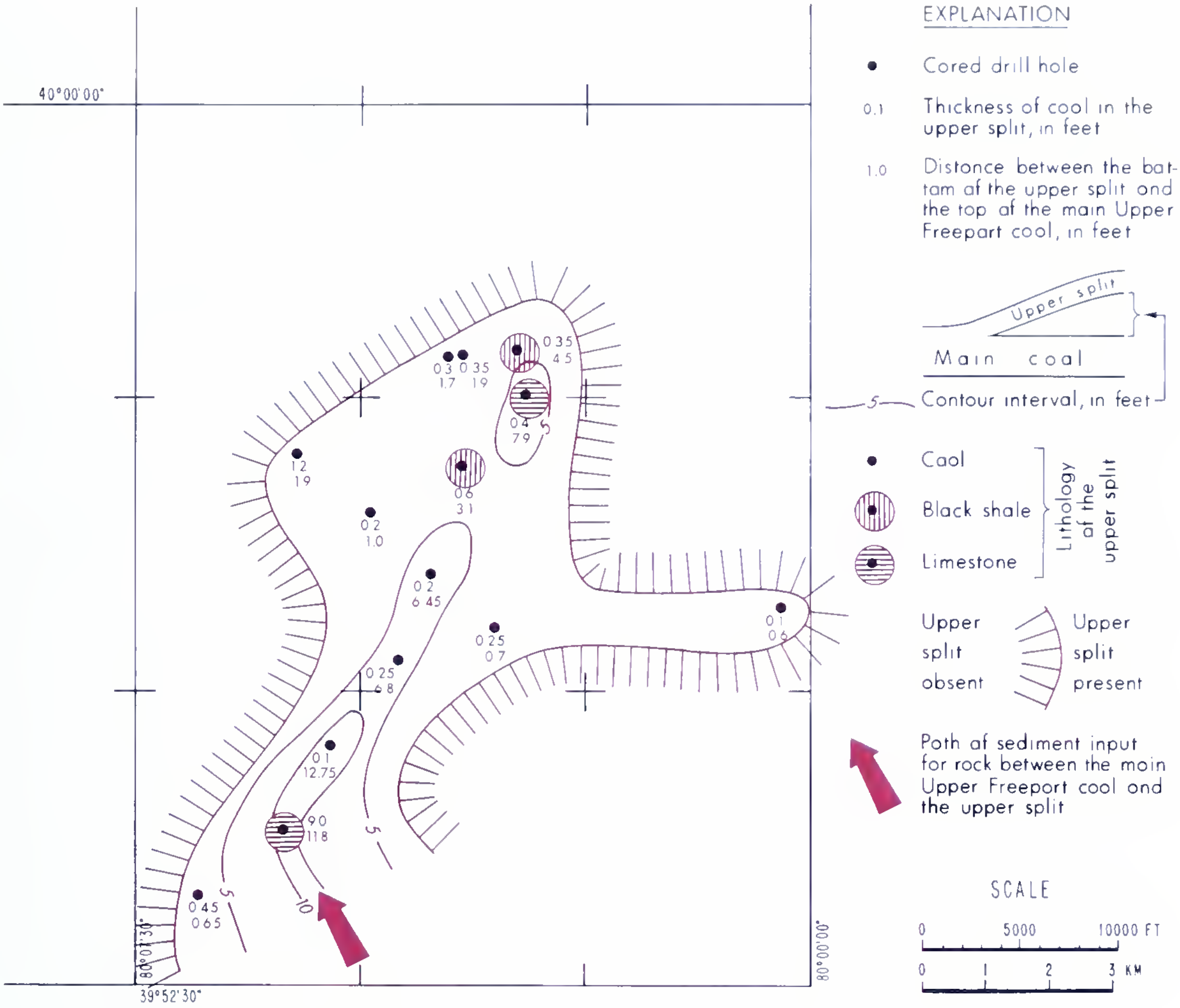

40°00'00"
EXPLANATION
Cored drill hole
0.1 Thickness of coal in the upper split, in feet
1.0 Distance between the bottom of the upper split and the top of the main Upper Freeport coal, in feet
Upper split
Main coal
5 Contour interval, in feet
Coal
Black shale
Limestone
Lithology of the upper split
Upper split absent
Upper split present
Path of sediment input for rock between the main Upper Freeport coal and the upper split
SCALE
0 5000 10000 FT
0 1 2 3 KM
0.35
4.5
0.3 0.35
1.7 1.9
0.4
7.9
1.2
1.9
0.6
3.1
0.2
1.0
0.2
6.45
0.25
0.7
0.1
0.6
0.25
6.8
0.1
12.75
9.0
11.8
0.45
0.65
5
10
80°07'30"
80°00'00"
39°52'30"

Figure 15. Distribution of the upper split of the Upper Freeport coal.

stone and sandy shale (Figure 3J). Two thin coals in hole 5446/1156, 13 feet (4 m) apart (Figure 3I), separated by silty shale, sandy shale, and about 0.5 feet (0.2 m) of sandstone, are probably Upper Freeport coal and indicate that the Upper Freeport coal splits towards the westernmost no-coal area.

Distribution of Sulfur and Ash

Sulfur content is generally low (Figure 16). A large area, approximately coincident with the thick coal containing no partings, has less than 1 percent sulfur. There is a general increase in sulfur content toward the margins of the coal and toward areas of thin coal.

Ash content ranges from 7.57 to 30.96 percent, and most values fall between 14 and 22 percent (Figure 17). There is no distinct pattern to the ash distribution. In contrast to the distribution of sulfur, there is no clear increase in ash content toward the margin of the coal body.

UPPER FREEPORT TO BRUSH CREEK INTERVAL

The sandstone overlying the Upper Freeport coal is present as lenticular units up to about 80

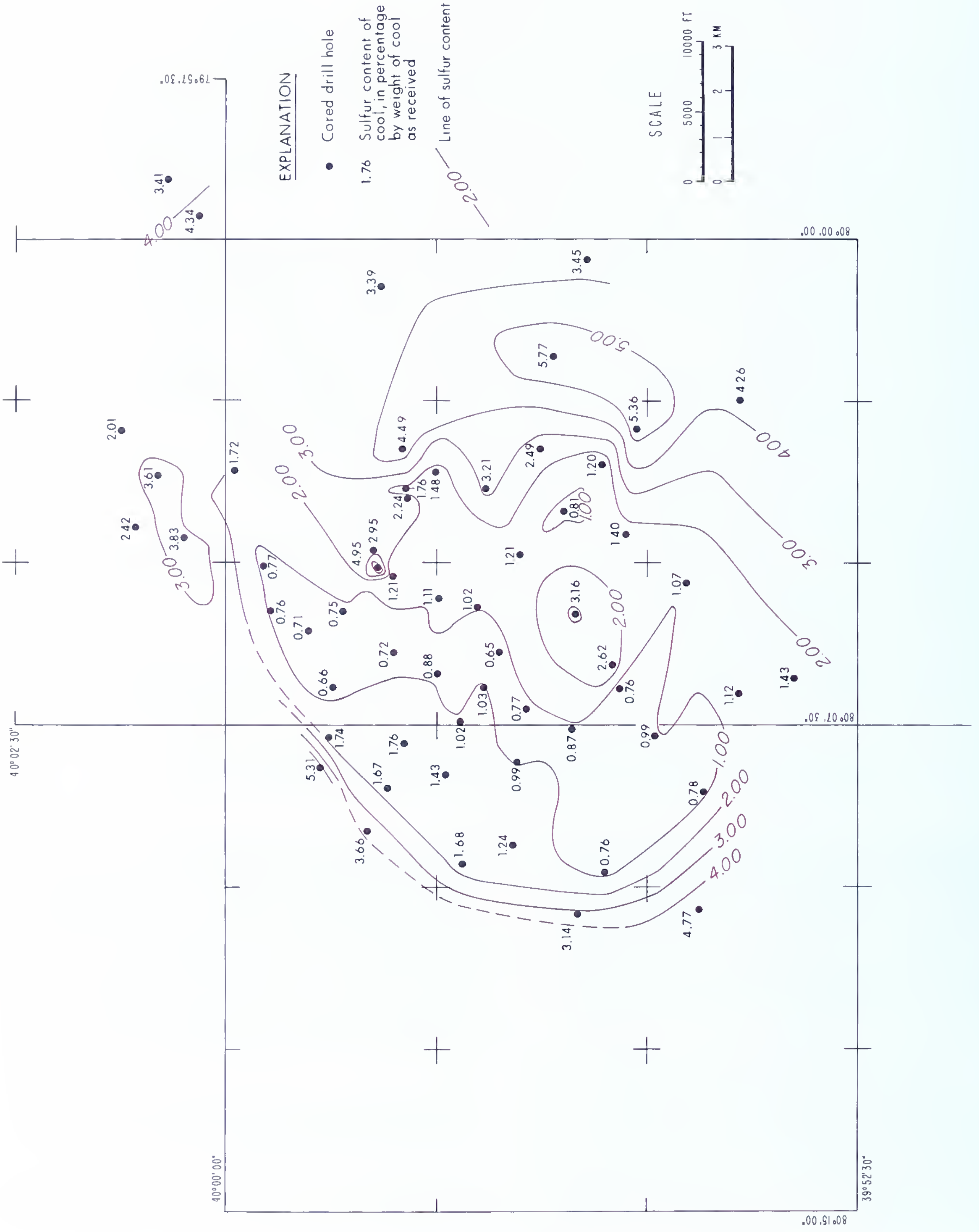


Figure 16. Sulfur content of the Upper Freeport coal.

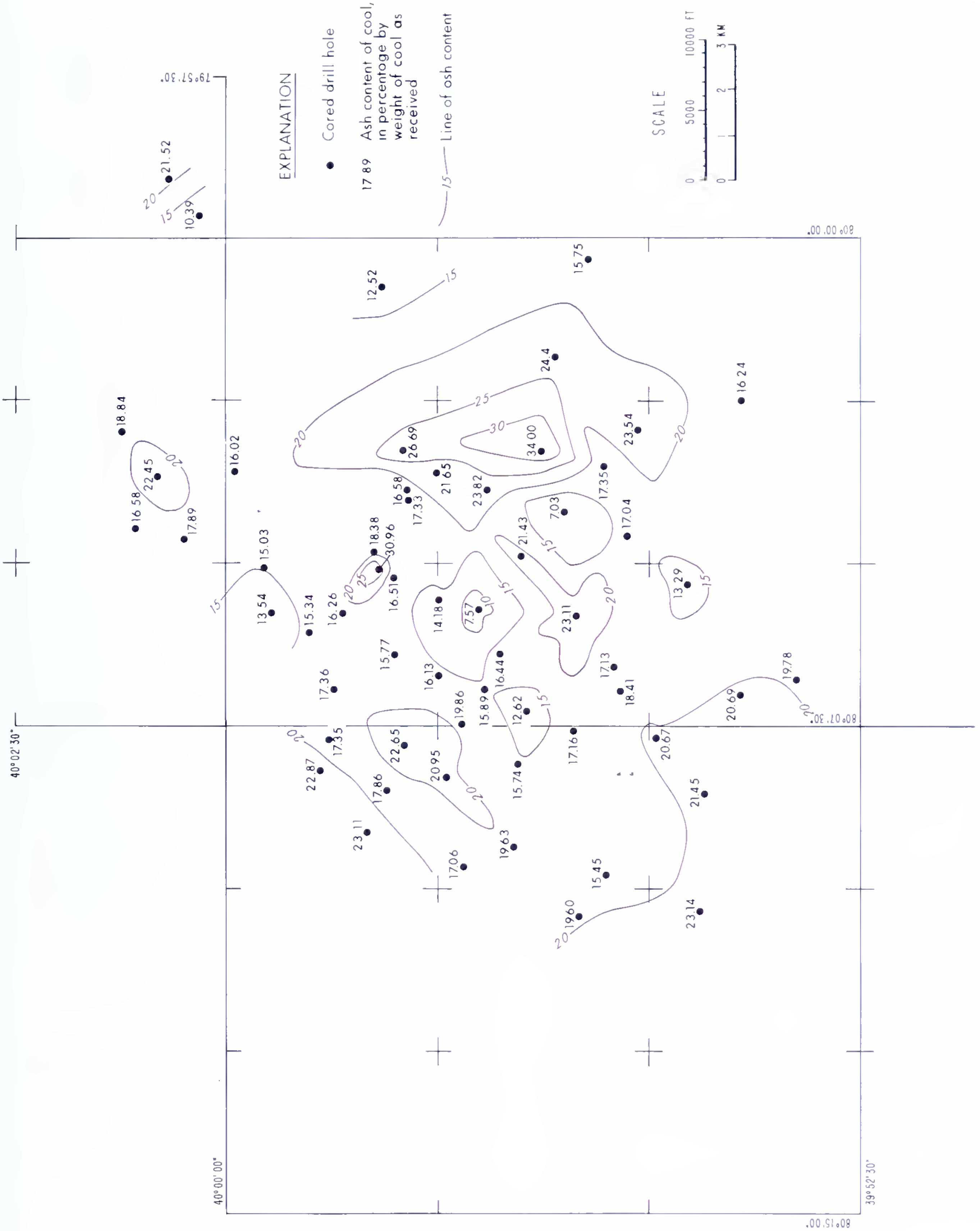


Figure 17. Ash content of the Upper Freeport coal.

feet (24 m) thick (Figure 18). On core logs where sandstone grain size is noted, individual subunits are recognizable and generally are less than 15 feet (4 m) thick. Grain size in these units varies from coarse to very fine. Rocks described as conglomerates are rare, and scoured surfaces, caused by downcutting fluvial channels, are not distinguished on the logs. Failure to distinguish scoured surfaces and absence of data on sedimentary structures eliminates many of the basic criteria used in vertical-sequence analysis (Harms and others, 1975, p. 63ff). A vertical-sequence analysis that was made using rock type and grain size as parameters showed a positive tendency for sandstone to become finer grained upward. This may indicate sand deposited by fluvial rather than marine processes (Bernard and others, 1970). Some core logs show that many sandstones in this interval consist of two or more fining-upward sequences. A more striking demonstration of a fining-upward sequence is given by gamma-ray logs of gas wells, which also clearly show stacked sets of fining-upward sequences (Figure 2). These stacked sets are arranged en echelon and are interpreted to coalesce, forming large, elongated sandstone bodies up to 80 feet (24 m) thick and over 4 miles (6 km) wide. These sandstone bodies increase in width upward (Figures 3, 5, and 6). Approximately 25 to 35 feet (8 to 11 m) above the Upper Freeport coal the sandstone complex covers most of the western two thirds of the study area from north to south.

This sandstone is nearly always laterally equivalent to sand-silt laminite or siltstone. A notable exception to this occurs in the north-central part of the Mather quadrangle, where, within the short distance of 800 feet (244 m) between drill holes, a 50-foot- (15-m-) thick sandstone unit is replaced laterally by a predominantly clay shale/claystone lithology. This area marks the western limit of a thick, no-sandstone area which occupies the northeastern part of the study area (Figure 19). One other appreciably large area of no sandstone overlies the coal along the Waynesburg-Mather quadrangle border. In this area the Upper Freeport coal is overlain by up to 37 feet (11 m) of carbonaceous clay shale capped by an additional 40 to 50 feet (12 to 15 m) of silt shale and sand-silt laminite. The areal distribution of this fine-grained zone corresponds well with the thick coal area of the Upper Freeport.

PALEOGEOGRAPHY

The interpretation of the paleogeography during the time of Upper Freeport coal development and soon after is best illustrated by a series of maps which show areal distribution of rock types at the Upper Freeport horizon and at different stratigraphic levels in the section above it (Figures 4, 5, 6, and 7). The rock distribution maps above the Upper Freeport represent slices taken through the rock at arbitrarily set distances above the coal. An interpretation is made of the depositional environments in which these sediments were deposited. There are limitations to this approach. Differences in compaction of dissimilar sediment types, the possible presence of downcutting stream channels, and original topographic relief during the deposition of these rocks all contribute to the probability that these slices do not represent a pure instant of time. Consequently, the rock distribution maps may not necessarily represent exactly contemporaneous environments of deposition. However, these maps in combination with some of the others already presented should provide a good general understanding of the types of environments that probably existed during and after the development of the peat at the Upper Freeport horizon.

The map showing distribution of lithologies and interpretation of depositional environments at the Upper Freeport horizon indicates the presence of a peat swamp covering most of the study area (Figure 4). At the core of this swamp and in a few small isolated areas near the edges, conditions were stagnant and there

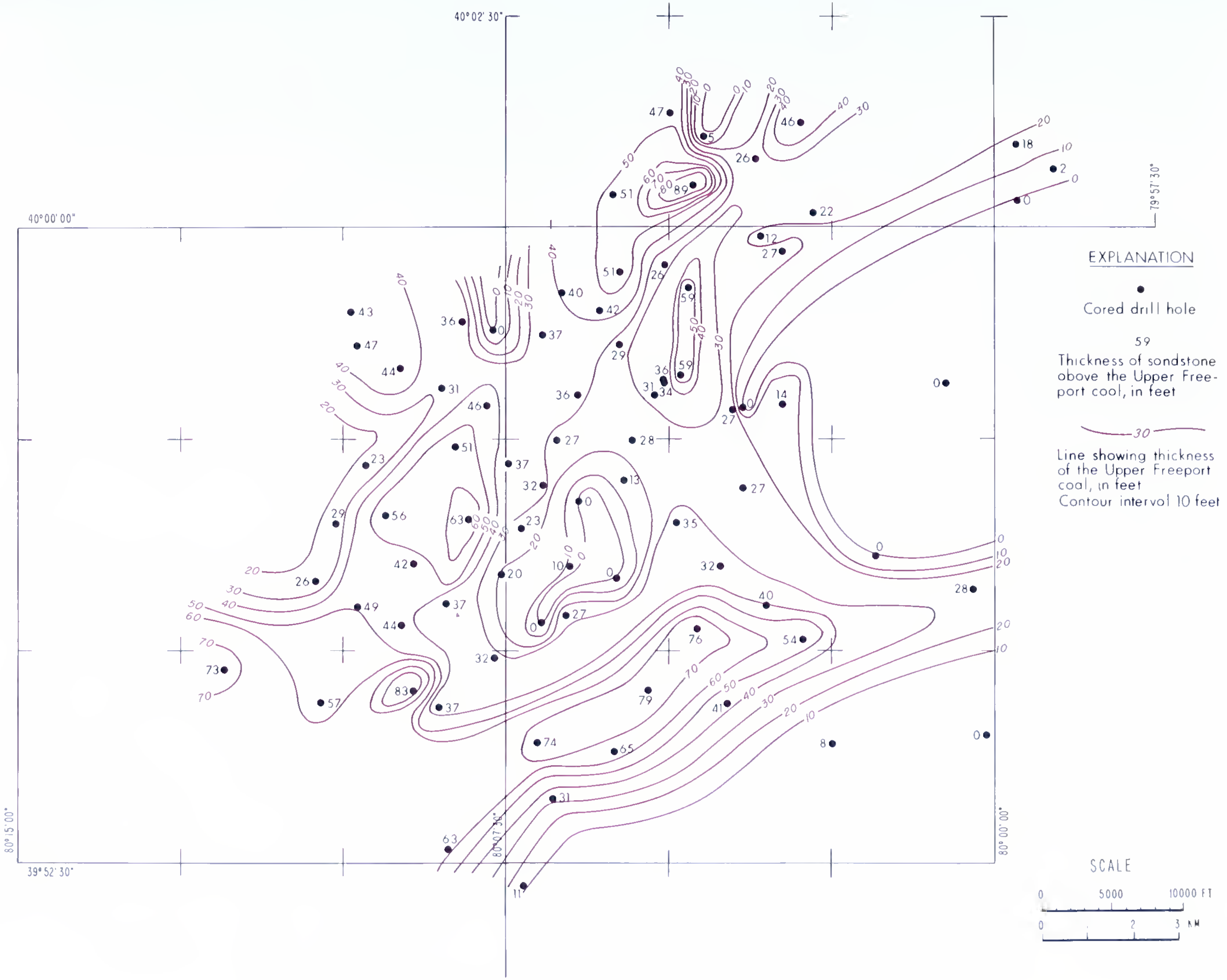


Figure 18. Thickness of the sandstone above the Upper Freeport coal.

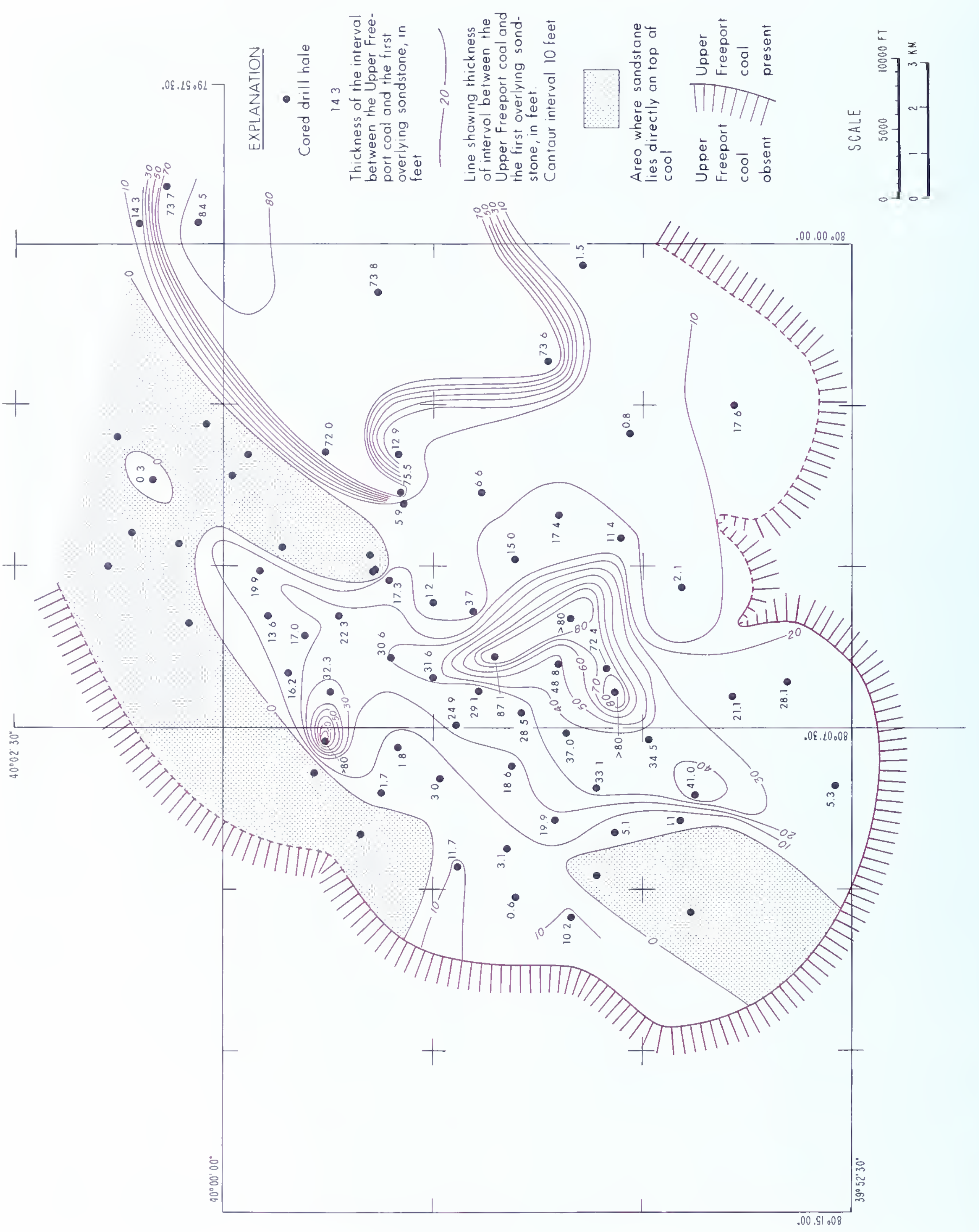

EXPLANATION
Cored drill hole
14 3 Thickness of the interval between the Upper Freeport coal and the first overlying sandstone, in feet
20 Line showing thickness of interval between the Upper Freeport coal and the first overlying sandstone, in feet. Contour interval 10 feet
Area where sandstone lies directly on top of coal
Upper Freeport coal absent
Upper Freeport coal present
SCALE
0 5000 10000 FT
0 1 2 3 KM
79°57'30"
80°00'00"
80°07'30"
80°15'00"
40°02'30"
40°00'00"
39°52'30"
14 3
73 7
84 5
73 8
1.5
73 6
72 0
12 9
75.5
5 9
0 3
0.8
17 6
6 6
17 4
11 4
15 0
19 9
17.3
1 2
3 7
2.1
13 6
17.0
22 3
30 6
31 6
>80
72 4
48 8
16.2
32.3
24 9
29 1
87 1
28 5
37.0
>80
34 5
21.1
28.1
>80
1 8
1.7
3 0
18 6
33 1
41.0
5.3
19.9
5.1
1.1
11.7
3.1
0.6
10 2
0
10
20
30
40
50
60
70
80

Figure 19. Thickness of rock between the Upper Freeport coal and the overlying sandstone.

was very little influx of sediment. These are now areas of thick coal that has no claystone partings. Coal that has partings nearly surrounds this area and was formed in an environment where sediment was periodically introduced to the swamp. The partings are most often thin and numerous, indicating intermittent sediment influx which probably did not result from any one period of major flooding (Figure 10). This sediment influx was most widespread during the early stages of peat development, and became considerably more localized as the swamp established itself (Figures 11 and 12). During the later stages of peat-swamp development, sediment input increased, as evidenced by numerous partings present near the top of the coal along the western boundary and in an area in the southern and west-central part of the Mather quadrangle (Figure 13). This latter area was also the site of a major incursion of clastic sediment which occurred during the final stages of peat-swamp development. The fanlike geometry and the laterally gradational reduction of grain size of this sediment going northward into the swamp (Figure 15) suggest that it is a crevasse-splay deposit which was the result of a breached levee located somewhere just south of the study area. A thin split of the main Upper Freeport seam covers these splay deposits and marks the brief reestablishment of the peat swamp in this area.

Sandstone in the area of no coal in the western part of the study area appears to have been deposited by a persistent fluvial system which existed contemporaneously with the peat swamp. The fact that the coal gradually thins and splits as it approaches this laterally adjacent sandstone area suggests that the coal was not removed by a downcutting fluvial channel present after peat deposition. Further evidence for this is the presence of what appears to be levee and overbank deposits separating the peat swamp and the stream channel (Figures 3H, 3K, and 4).

In the southeastern part of the study area, thinning and splitting of the Upper Freeport coal and the presence of thin fine-grained sandstones, claystones, and argillaceous limestones at the position of the coal possibly indicate a shallow pond or lake environment (Figures 3G and 4).

The thick, wide sandstone bodies containing multistoried sets of fining-upward sequences that overlie the Upper Freeport coal in much of the area were deposited by a relatively fast flowing meandering stream system. This stream system appears to have migrated laterally onto the swamp from the west, terminating peat development. At the same time, a separate stream cut a channel in the central and southeastern portion of the peat swamp. The path of this channel is nearly the same as the path of the underlying crevasse splay and the area where coal containing numerous upper partings is present, suggesting that this may have been a topographically low area (slightly deeper bottom) in the swamp for some time (Figures 13 and 15). Conversely, the area of thick coal having no partings along the Waynesburg and Mather quadrangle border is overlain by a thick carbonaceous claystone, indicating an area of very low water velocity which was also present for some time and may have been topographically high (Figures 4, 5, and 6).

These features of the coal and overlying rock suggest that the termination of peat development was not caused by a sudden incursion of sediment throughout the swamp. Instead the process was a progressive drowning of the peat swamp. Certain parts of the swamp received recurring influxes of sediment while other areas were unaffected. This process eventually led to the development of permanent channels along the pathways of sediment influx. As flow velocity and sediment load increased in these channels, the quiet areas of peat development became more restricted in size. Eventually they became areas of clay deposition that had very little preservation of organic material.

The mechanism for containing sediment input within limited areas of the swamp may have been related to the ease of compactibility, which is characteristic of peat. Minor influxes of sediment into limited areas of the swamp could have accelerated compaction of the peat in these areas and created a slight depression. This topographic low could have provided a more favorable downward gradient for the diversion of additional sediment into these areas. Another possible cause for the development of these channels may have been the presence of slight differences of elevation in the swamp prior to peat development. Not enough is known about the rocks underlying the coal to determine whether these differences in elevation existed, nor to understand the possible causes for them. Knowledge of the genesis and distribution of these sediment-carrying channels which develop in the late stages of a peat swamp can be economically important. Streamflow in these channels can eventually reach a high enough energy level so that there is scouring of the underlying peat. These erosional features are serious detriments to mining and any knowledge of their possible existence would be beneficial to mine planning.

The stream system that terminated peat development and buried the swamp with thick deposits of sand and silt over a wide area eventually narrowed and appears to have lost energy, especially in the northwest, where backswamp deposits consisting of clay shales, calcareous claystones, and limestones became widespread at about 50 feet (15 m) above the coal (Figure 7).

THE DEPOSITIONAL ENVIRONMENT

The geometry of the thick, elongate, meandering-stream deposits, the locally thick but laterally discontinuous Upper Freeport coal, the calcareous shallow pond or lake deposits laterally equivalent to the coal, and the absence of brackish and marine fossils are all factors characteristic of an upper delta plain environment.

A depositional model of this environment in northeastern Greene County during the time of Upper Freeport deposition consists of a north- to northeast-oriented river channel and associated levees. Flanking the river to the east is a well-developed peat swamp 5 to 10 miles (8 to 16 km) wide. Further eastward the peat swamp is less well developed and interspersed with freshwater lakes and ponds.

During times of normal flow velocity the river channel in this upper delta plain environment would have a meandering course resulting in the development of point-bar deposits. Such a meander belt bounded by levee deposits is approximately 1 to 7 miles (1.6 to 11 km) wide and can have a relatively straight, linear distribution for tens of miles (Donaldson, 1974; Horne and others, 1978; Frazier and Osanik, 1969). Occasionally, during times of flood, the levees are breached in places along the main river channel and some streamflow is diverted laterally through the adjoining peat swamp and into the topographically lower lake and pond area of the backswamp. Peat development along these offshoot splays and stream channels is retarded or permanently arrested. This process directs the well-developed peat swamp flanking the main river channel into islands of thick peat surrounded by thin peat or clastic sediments. The end result is a roughly linear distribution of a series of thick peat islands in a 5- to 10-mile- (8- to 10-km-) wide zone adjacent to and paralleling the sandy levee and point-bar deposits of the main river system.

APPLICATION OF THE MODEL

The depositional model developed by comparing the data from northeastern Greene County with studies of modern deltaic sedimentation can be a useful tool for regional exploration in the portions of Greene and Washington Counties adjoining the study area. The drill hole data from the study area reveal a thick pod of coal adjacent to sandstone channel deposits trending in a north to northeast direction. Based on the depositional model developed in this study it can be expected that other thick pods of coal were developed on the eastern flank of this channel system. The most efficient method of exploration for these thick pods would be a series of lines of drill holes perpendicular to the river channel meander belt. Spacing the drill holes approximately 2.5 miles (4 km) apart along lines trending west-west-north and east-east-south and spacing the lines 5 to 10 miles (8 to 16 km) apart starting from the center of the known pod of coal should more precisely delineate the river channel direction and also give a good probability of penetrating other thick pods of coal. Since a similar, symmetrically opposite, backswamp development is possible on the other side of the channel meander belt, some of these lines of drill holes should cross the channel system.

ROOF ROCK CONDITIONS

The nature of the rocks immediately overlying the minable coal is an important consideration in mine design and choice of mining techniques to be used. The Upper Freeport coal in northeastern Greene County is overlain by a variety of rock types (Figure 20). An attempt will be made to list the potentially bad roof situations which appear to be present in this particular geologic setting.

A major cause of roof falls that is not related to joints is the presence of compactible clay or silt shale marginal to abruptly thickening lenses of channel-fill sandstone (Kent, 1974; Moebs, 1977). These shales are broken apart and weakened because of differential compaction. This situation is possibly present in the north-central and west-central portions of the Mather quadrangle (Figures 18, 19, and 20).

Severe roof problems can also occur where a rider coal or split is present within 20 feet (6 m) of the main seam, and separated by fine-grained sediment (Horne and others, 1978). Such a split occurs in the Mather quadrangle and is outlined on the roof-rock map (Figure 20). The thin coal capping the splay sediments is a potential zone of weakness at which separation can occur, bringing down all of the underlying rock in a roof fall.

A more predictable source of roof problems can be related to structural features of the rocks. In northeastern Greene County, these roof falls occur along the northeast-trending sets of joints where shales overlie the mined coal. This type of roof fall can be minimized by orienting mine workings about 45 degrees from the cleat directions in the coal.

STRUCTURE

The rocks of northeastern Greene County are gently folded into broad anticlines and synclines which generally trend in a northeast-southwest direction (Figure 8 [centerfold]). The major structure within the study area is the Bellevernon anticline. Its axis trends about N45E and there is a gradual double plunge to a saddle in the southwestern part of the Mather quadrangle. Its western limb dips uniformly northwestward into the Waynesburg syncline. East of the Bellevernon anticline, the structure is flatter and more disordered. Several fold structures disappear in this flat area directly east of the study area (Kent, 1969). The terminus of a short branch of one of these folds, the Whiteley syncline, is apparent in the south-central part of the Mather quadrangle and is herein designated the Muddy Creek branch (Figure 8). A structure-contour map drawn on the top of the Upper Freeport coal in the study area (Figure 8) compares well with previous mapping of structure on the Pittsburgh coal by geologists of the U.S. Geological Survey (Berryhill and Schweinfurth, 1964; Schweinfurth, 1967; Kent, 1969; Roen, 1970).

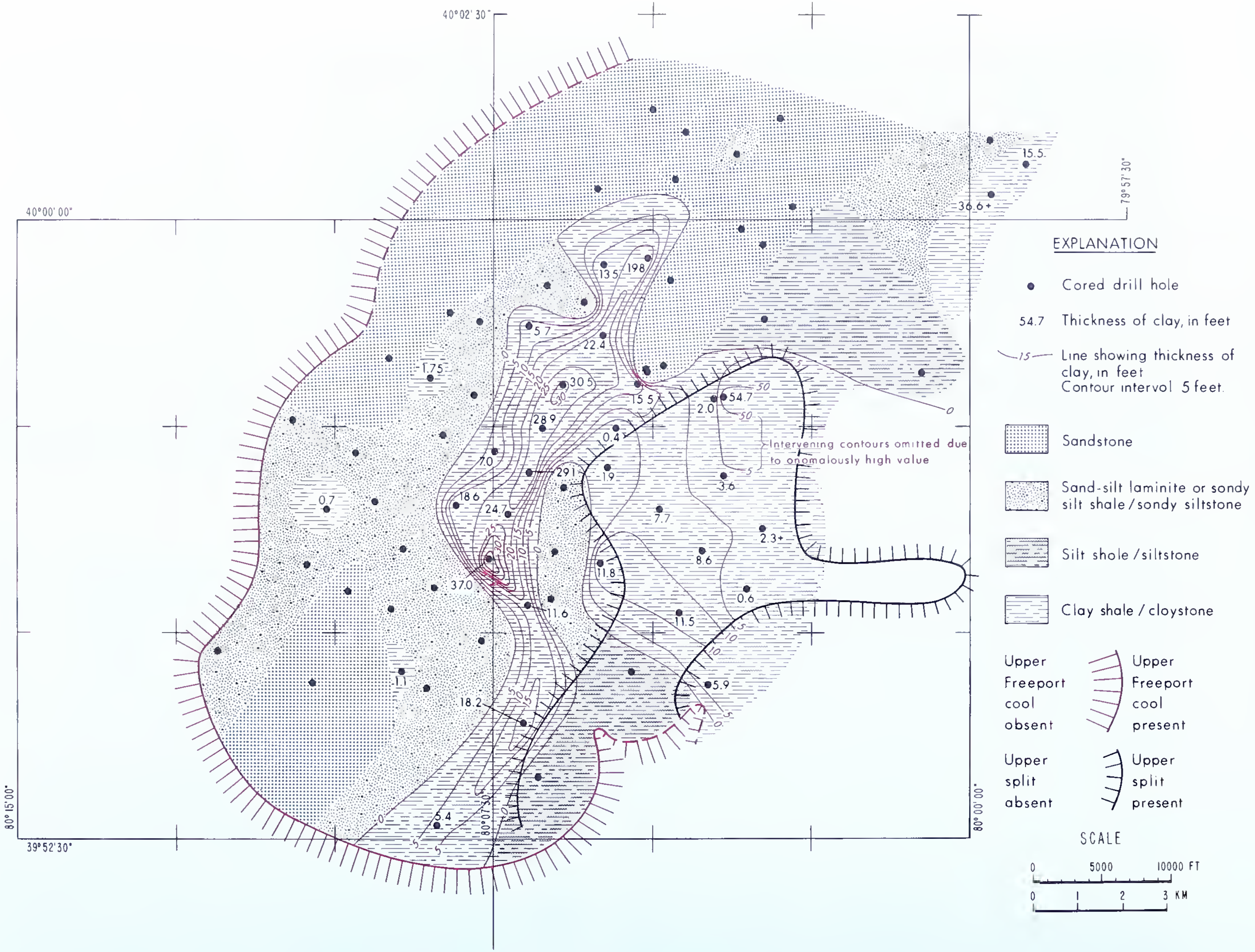


Figure 20. Roof rock map of the Upper Freeport coal.

Data showing orientation of cleat surfaces in the Upper Freeport coal are unavailable. Cleat in the Upper Freeport coal should have similar strike and spacing to cleat in the Pittsburgh coal above it (McCulloch and others, 1976). The U.S. Bureau of Mines has published several reports giving cleat orientation of the Pittsburgh coal in the Jones and Laughlin Steel Corporations' Gateway mine, which is located in the study area (McCulloch and others, 1974). Reported directions of cleat are N68W for face cleat and N28E for butt cleat. Published data giving orientations of bedrock joints in northeastern Greene County are also available (McCulloch and others, 1975; Bench and others, 1977). The dominant bedrock joint orientation in the Mather quadrangle consists of a joint set trending N77W and a set trending N13E. In the adjacent Waynesburg quadrangle a third dominant joint set trending N57W is present. Similar bedrock jointing and coal cleat orientations should be found in deeper rocks directly below where these were measured.

In order to prevent any of the roof problems related to jointing, the optimum orientation for mine workings in the Upper Freeport coal in northeastern Greene County should be approximately N23W and N67E.

UPPER FREEPORT COAL RESOURCES

An evaluation of the important economic characteristics of the Upper Freeport coal in northeastern Greene County shows that the coal has considerable potential for future development. At the time this paper was written, mining of the Upper Freeport coal in the study area had not been initiated. The coal underlies 55,395 acres (224 km^2) of the area at depths of 985 to 1,500 feet (300 to 457 m). Most of the coal has no partings or only a few minor partings. The coal body is lense shaped. It is 10 miles (16 km) wide in an east-west direction and 13 miles (21 km) long in a north-south direction. There is a relatively uniform westward thinning, giving a well-defined western and southwestern limit to the coal body. In the eastern part of the report area, there is no clearly discernible boundary to the coal. Areas of relatively thick coal are interspersed with areas where coal is thin or absent. Within the main body there is 33,058 acres (134 km^2) of coal having a thickness of 42 inches (107 cm) or more. The maximum thickness, excluding partings, is 104 inches (264 cm) (Figure 21). The sulfur content in most of this area of thick coal ranges from 0.81 to 2 percent. The ash content ranges from 7 to 24 percent.

For the purpose of estimating coal resources, the thin coal split above (Figure 20), and the two thin coals immediately below, the main seam (Figure 19) were not considered. Because sulfur- and ash-content figures were not available on a bench-by-bench basis, no specific benches could be excluded from the estimates because of poor quality. Partings more than 3/8 inch (0.95 cm) thick were disregarded in determining thickness (Averitt, 1969).

Resource calculations of the Upper Freeport coal within the boundaries shown on Figure 21 are given in Table 1. These estimates are based on data obtained prior to January 1, 1978, at which time no mining of the coal had taken place. Definitions of the terms used to indicate reliability of the estimates can be found in the standard U.S. Bureau of Mines-U.S. Geological Survey coal resource classification system (U.S. Bureau of Mines-U.S. Geological Survey, 1976). In this report, "measured" resources lie within 1/4 mile (0.4 km) of a drill hole, "indicated" resources lie between 1/4 mile and 3/4 mile (0.4 and 1.2 km) from a drill hole, and "inferred" resources lie beyond 3/4 mile (1.2 km) from a drill hole.

A point-count method was used in obtaining the estimated coal tonnage figures (Wells, 1972). In this approach, the coal resource map is overlain by a grid of evenly spaced points.

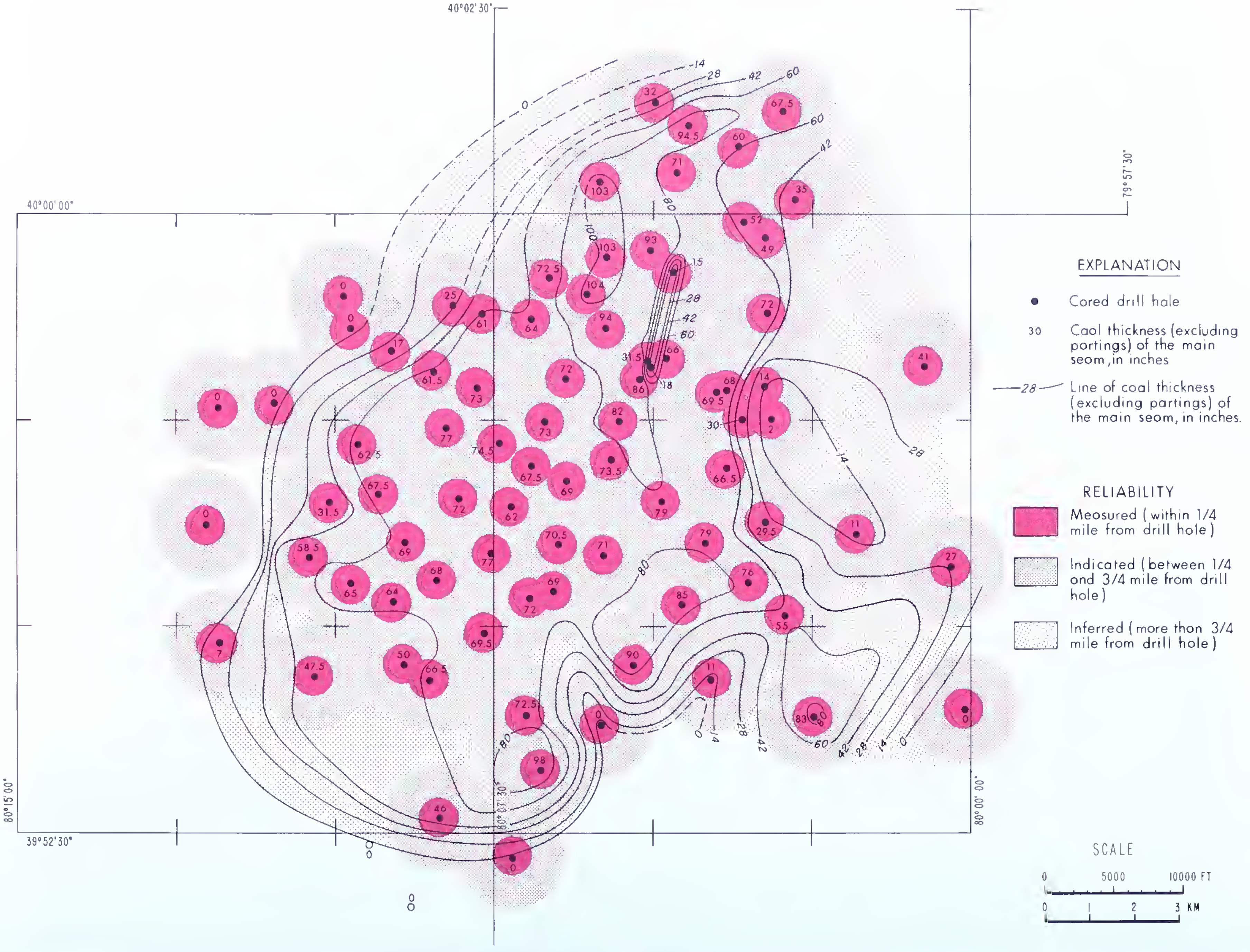

40°02'30"
40°00'00"
39°52'30"
79°57'30"
80°00'00"
80°07'30"
80°15'00"
EXPLANATION
● Cored drill hole
30 Coal thickness (excluding partings) of the main seam, in inches
—28— Line of coal thickness (excluding partings) of the main seam, in inches.
RELIABILITY
Measured (within 1/4 mile from drill hole)
Indicated (between 1/4 and 3/4 mile from drill hole)
Inferred (more than 3/4 mile from drill hole)
SCALE
0 5000 10000 FT
0 1 2 3 KM

Figure 21. Resource map of the Upper Freeport coal.

Table 1. *In-Place Identified Coal Resources of the Upper Freeport in Northeastern Greene County*

(Quantities are in thousands of short tons; thousands of metric tons are in parentheses)

	Demonstrated		Total demonstrated		
	Measured	Indicated		Inferred	Total
14 inches (36 cm)	86,194.9	266,907.7	353,102.6	51,525.5	404,628.1
and over	(78,194.7)	(242,134.6)	(320,329.3)	(46,743.1)	(367,072.4)
28 inches (71 cm)	84,121.9	254,297.5	338,419.4	41,332.7	379,752.1
and over	(76,314.1)	(230,694.8)	(307,008.9)	(37,496.4)	(344,505.3)
35 inches (89 cm)	82,964.0	244,438.7	327,403.6	33,295.4	360,699.0
and over	(75,263.7)	(221,751.1)	(297,015.5)	(30,205.1)	(327,220.6)
42 inches (107 cm)	79,211.4	227,892.6	307,104.0	21,794.1	328,898.1
and over	(71,859.4)	(206,740.7)	(278,600.1)	(19,771.3)	(298,371.3)
14 to 28 inches	2,073.0	12,610.2	14,683.2	10,192.8	24,876.0
(36 to 71 cm)	(1,880.6)	(11,439.8)	(13,320.4)	(9,246.8)	(22,567.1)
28 to 42 inches	4,910.5	26,405.0	31,315.5	19,538.6	50,854.1
(71 to 107 cm)	(4,454.7)	(23,954.2)	(28,408.9)	(17,725.1)	(46,134.1)

Each point represents a constant area. A thickness and a reliability category are assigned to each of these areas. Values for each point are then multiplied by the specific gravity of an average value for bituminous coal (1,800 tons/acre-foot or 1,323,928 MT/km^2). In this study 2,413 points were used, giving each point a value of 22.957 acres (0.093 km^2).

A problem not encountered up to now in deep mining of coal in Pennsylvania is the presence of saline groundwater. The Upper Freeport coal in the study area is more than 500 feet (150 m) beneath the lowest local points of groundwater discharge. Water at these depths would be stagnant, and there is a good possibility of encountering connate brine in any existing aquifers. Only one record, a driller's log of a gas well in the Waynesburg quadrangle, was found giving information on quality of groundwater, and it did not indicate the presence of saline water at or near the Upper Freeport horizon 900 feet (274 m) beneath the surface. However, the occurrence of brine associated with oil in the sandstone overlying the Upper Freeport coal was mentioned by McGlade in the Amity quadrangle north of the study area (McGlade, 1967). The potential for a similar occurrence in the study area is good and the possibility should be evaluated. An environmentally safe means of disposing of such brine, once it is pumped from the mine, could be an important economic factor in mining the coal.

CONCLUSIONS

The Upper Freeport coal in the area of northeastern Greene County is present as a thick, minable coal in a relatively limited area bounded by areas of no coal or thin coal. The coal is an oval pod that covers an area of 86 square miles (224 km^2) and contains 79,211,400 tons (71,859,373 MT) of measured reserves of coal greater than 42 inches (107 cm) thick.

The Upper Freeport coal of this study area probably formed in an upper delta plain. The peat swamp in which the coal originated was situated on the flanks of a north- to northeast-oriented meandering-river channel system. Freshwater lake deposits interspersed with thin peat deposits were forming to the east and south of the main swamp. During times of flood, streamflow was temporarily diverted from the main channel through the peat swamp and into the lower lying lakes. This process caused the breaking up of the peat into elongate peat islands. Even when major flooding finally terminated development of peat throughout the area, these secondary stream channels continued to carry the bulk of the sediment load. Consequently the submerged thick peat islands remained quiet backwater areas where only clays were deposited.

The meander belt of a major river in an upper delta plain environment such as the one seen in northeastern Greene County is likely to have a linear distribution for tens of miles. Other thick peat islands can be expected to flank this meander belt. Consequently additional exploration seems most profitable to the northeast and southwest of the thick coal found in the study area.

A major hazard that may be encountered in mining the Upper Freeport coal in northeastern Greene County is the occurrence of weak roof conditions in the area where the rock overlying the coal is a thick clay shale. Bad roof conditions are especially likely along the margins of this clay shale where it is adjacent to a thick sandstone body and in the area containing a thin split of the Upper Freeport coal. Another possibly troublesome area is on the eastern side of the minable coal area, where the coal is overlain by sandstone. It was here that a very narrow, elongated area was identified where the coal was nearly cut out by the stream channel system which developed over the peat swamp. The narrow dimensions of this type of cutout make it very probable that others may exist in the area overlain by sandstone, and may not be identified in exploratory drilling.

Finally, it must be emphasized that this study establishes the environment of deposition for a limited area. For an understanding of the characteristics of the Upper Freeport elsewhere in western Pennsylvania, this report should be supplemented by regional studies which will allow many paleogeographic maps to be constructed for all of western Pennsylvania so that it will be known with some confidence what depositional patterns to expect. This could be accomplished by a few studies in properly selected, key areas.

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